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Let’s talk about climate change

Emiliano Merlin
INAF OAR
2.4.2024

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1. Is climate changing? Is it caused by human activities? Is this debated by experts?
2. Can we foresee the consequences of climate change?
3. Which are its physical causes?
4. Which human activities are more impactful?
5. What can/should we do?

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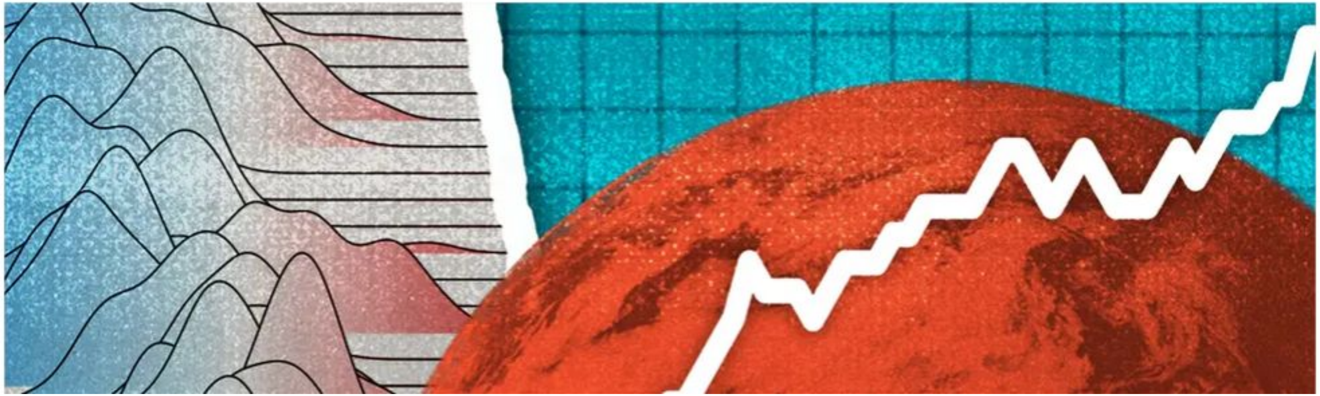
2023 confirmed as world's hottest year on record

9 January · Comments

Climate



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HOME CATEGORIE GALLERY MEDIAINAF TV INAF

ROTAZIONE TERRESTRE FRENATA DALLO SCIOGLIMENTO DEI GHIACCI

Così il cambiamento climatico altera il tempo

Il riscaldamento globale, facendo sciogliere i ghiacciai, porta – secondo uno studio uscito questa settimana su Nature – a un rallentamento della rotazione terrestre, contrastando il trend opposto che si evidenziava ormai da qualche anno. E ritardando di almeno tre anni la necessità (e il rischio) di dover fare ricorso – per la prima volta – ai secondi intercalari negativi. Con un commento di Patrizia Tavella, direttrice dell'International Bureau of Weights and Measures

Valentina Guglielmo 29/03/2024

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Surriscaldamento climatico, registrate temperature record ai due poli. In Antartide 40° gradi sopra la media

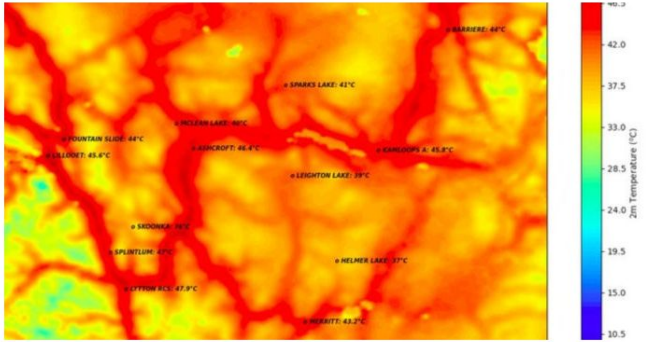
Secondo gli scienziati, questa ondata di caldo che è in atto in Antartide, ha come origine il gran caldo che ha investito il sud America durante la stagione estiva, e che alla fine sta influenzando il clima di quello che il luogo più freddo del nostro Pianeta

AudioPlay · Ascolta l'articolo

0:00

di F. C. | 19 MARZO 2022

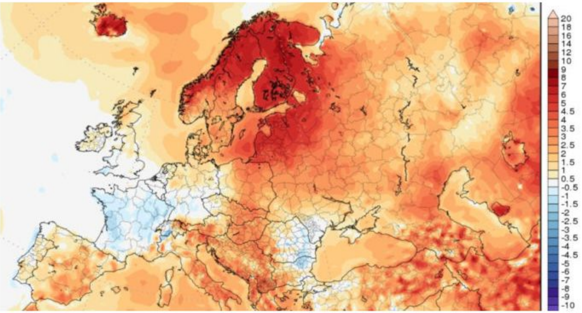
Riscaldamento globale, Canada verso i 50 gradi, oltre 200 morti. L'esperto: "Saltati tutti i parametri della climatologia passata"



Temperature fuori norma anche in molte zone degli Stati Uniti. La scorsa settimana nella Russia artica si sono raggiunti i 40 gradi. Dati che sostengono i ripetuti allarmi degli esperti che sottolineano in particolare come l'umanità sia molto in ritardo nell'adattamento ad una situazione di cambiamento climatico ormai inevitabile.

di Mauro Del Corno | 30 GIUGNO 2021

Riscaldamento globale, al circolo polare artico le stesse temperature di Palermo. Nel Nord della Norvegia 34 gradi



Temperature di 10/15 gradi superiori alla norma in tutto il Nord della Scandinavia. Nella zona norvegese al di sopra del circolo polare si superano i 34 gradi. Allarme Onu: "Nessun rallentamento nel livello di emissioni e di aumento delle temperature globali"

di Mauro Del Corno | 6 LUGLIO 2021

— RISCALDAMENTO GLOBALE

28 Marzo 2022

In aumento sia le temperature minime che le massime

Clima, Istat: città italiane sempre più calde, +1,2 gradi rispetto al 2000

Dal 2014, la temperatura media ha raggiunto i +16 gradi, "segnale di un riscaldamento in atto nei sistemi urbani". Il 2020 è anche l'anno meno piovoso dal 2011

Clima, l'inverno più caldo di sempre in Europa: 3,4 gradi in più della media

MONDO

Giovedì 2 Aprile 2020

Il vertice sul clima di Glasgow, il Cop 26, viene rinviato per l'emergenza coronavirus, proprio il mentre arriva la notizia che l'inverno appena trascorso è stato il più caldo di sempre in Europa. Con una media di 3,4 gradi in più rispetto al periodo di riferimento 1981-2010, infatti, la passata stagione supera il primato che spettava all'inverno 2015-2016.

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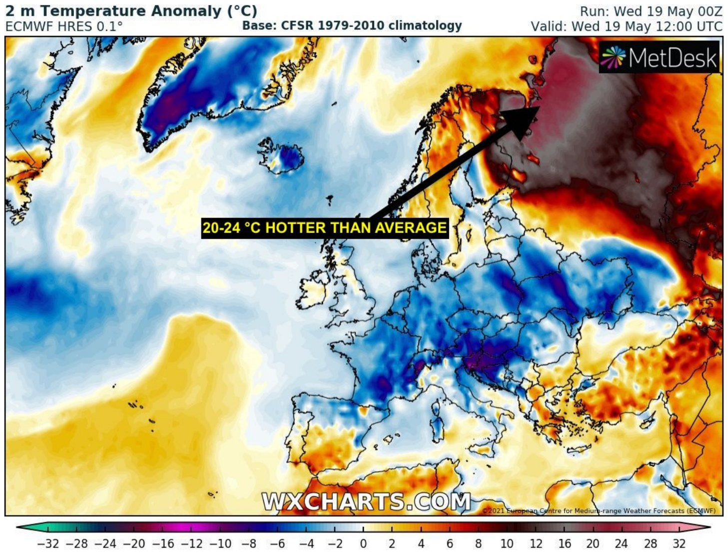
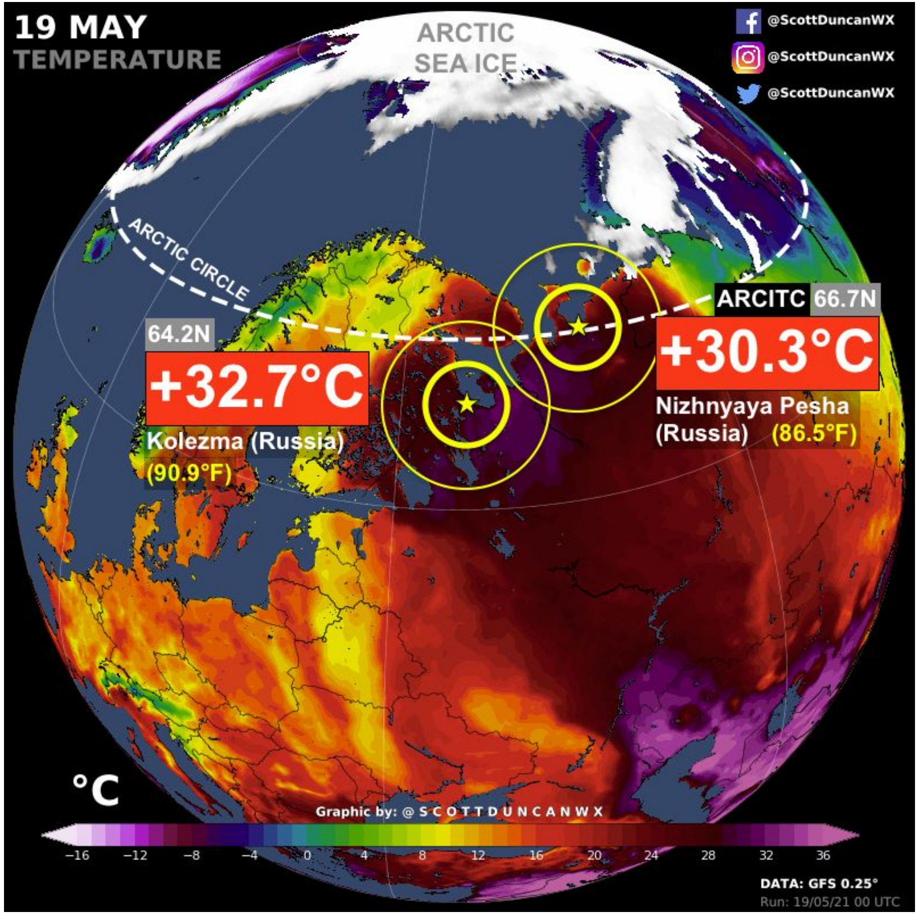
2021





https://twitter.com/ScottDuncanWX/status/1395039582522122249/photo/1

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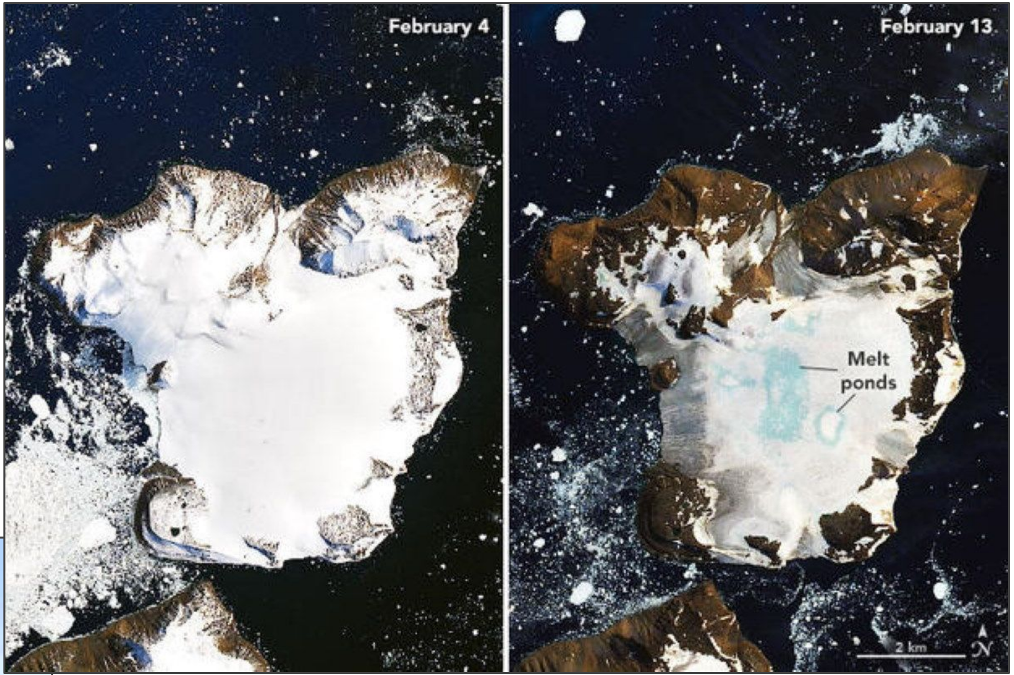
2020



https://twitter.com/NASAEarth/status/1230869802199191553

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2019

Australia, le conseguenze apocalittiche del caldo record

AMBIENTE Pubblicato il 23 GEN 2019 di ELISABETTA SCURI

I pipistrelli cadono dagli alberi, i pesci muoiono, la frutta si cuoce prima che venga raccolta: le temperature eccezionalmente alte stanno mettendo a dura prova l'Australia.

Australia, il caldo record tocca un nuovo picco: temperatura media a 41,9°. Centinaia gli incendi

Superato per il secondo giorno consecutivo il record del 2013 di 40,3 gradi. Martedì la media nazionale era stata di 40.9°. Il direttore del programma per il clima: "Fenomeno legato ai cambiamenti climatici in termini di gravità e durata"

di F. Q. | 19 DICEMBRE 2019

Incendi in California, per la prima volta è "allarme rosso estremo": riguarda 26 milioni di persone. Solo il 15% dei roghi è stato domato

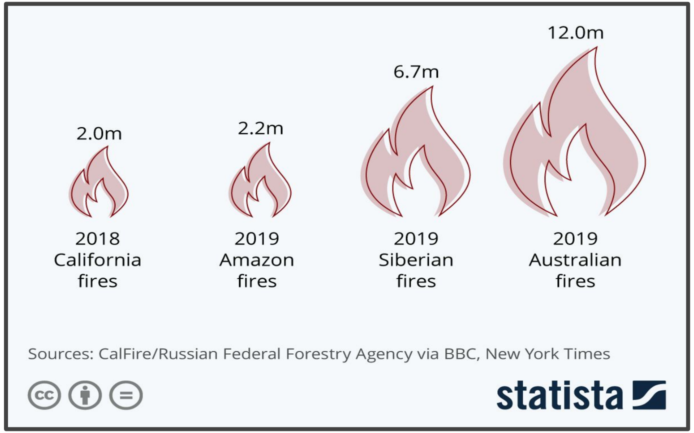
Le fiamme stanno bruciando migliaia di ettari dallo Stato della West coast fino all'Arizona: nella Simi Valley minacciano la Biblioteca presidenziale di Ronald Regan, mentre il Kincade Fire sta devastando i vigneti della Sonoma Valley. Quasi due milioni le persone rimaste senza luce e gas

di F. Q. | 30 OTTOBRE 2019

Siberia in fiamme, Greenpeace: "Bruciata un'area grande come la Grecia". Ignorati 295 incendi: "Spegnerli costa troppo"

Secondo l'organizzazione ambientalista, quest'anno le fiamme hanno raso al suolo 13 milioni di ettari. Molti degli incendi che stanno divampando nel Paese avrebbero potuto essere estinti in fase precoce. Tra i danni collaterale l'emissione di CO2 e di 'black carbon'

di F. Q. | 6 AGOSTO 2019



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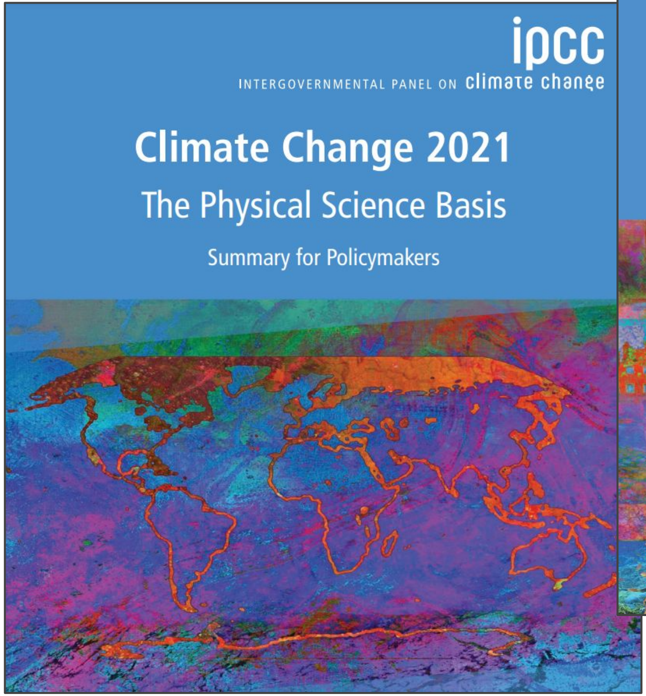
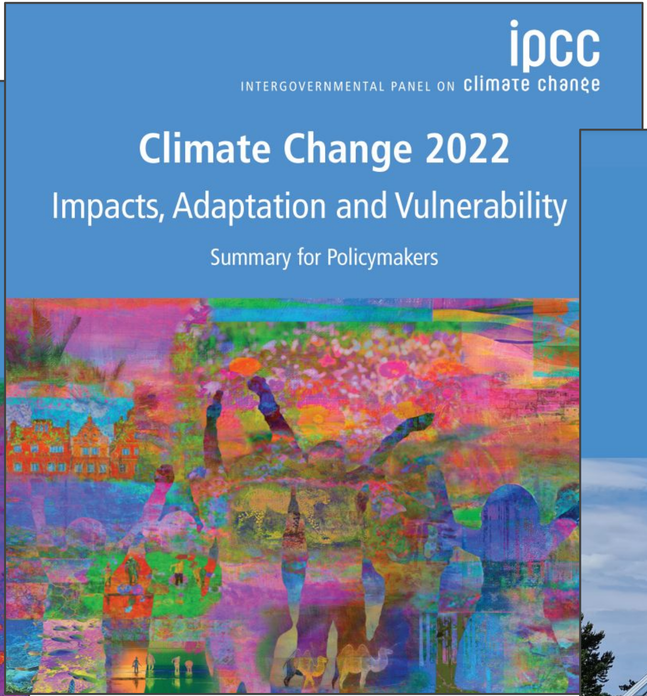
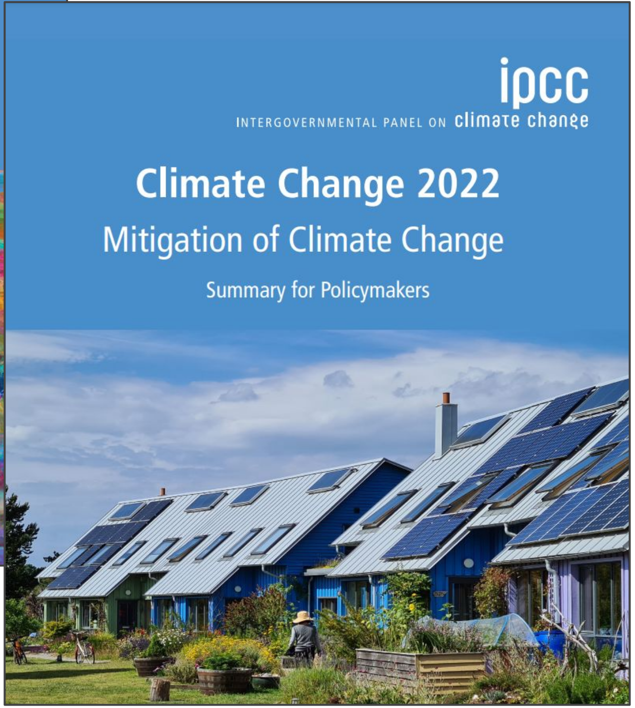
IPCC 2021-2022 REPORTS







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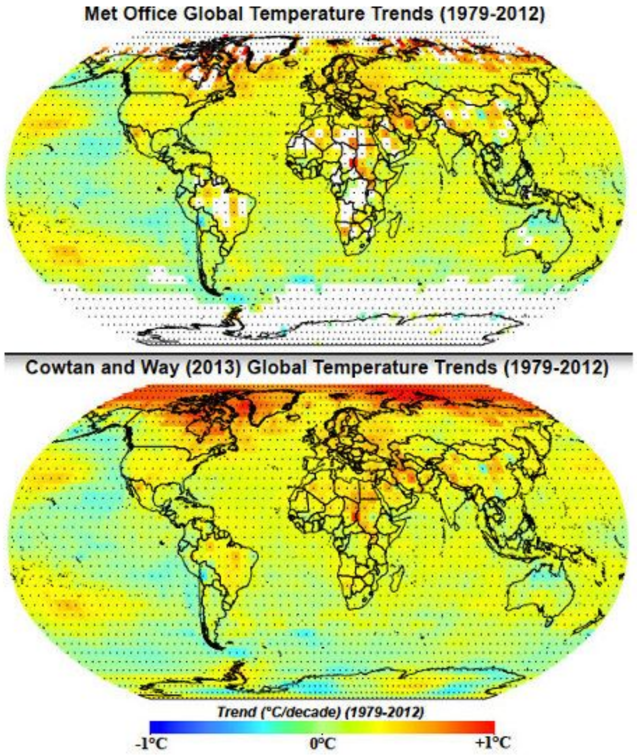
How do we measure the temperature of the planet?



- Direct measurements on the surface of Earth with stations, boats, balloons, satellites
- Monthly averages vs. 30-years average, assessing local anomalies
- Grid of global data, global average, comparison vs models
- 4 main datasets:
  - **HadCRUT** (UK Met, since 1850, 5° box)
  - **GISTEMP** (USA, NASA, since 1880, 99% cop., 2° box)
  - **MLOST** (USA, NOAA, since 1880, 5° box)
  - **JMA** (Japan, since 1891, 85% cop., 5° box)

https://www.carbonbrief.org/explainer-how-do-scientists-measure-global-temperature

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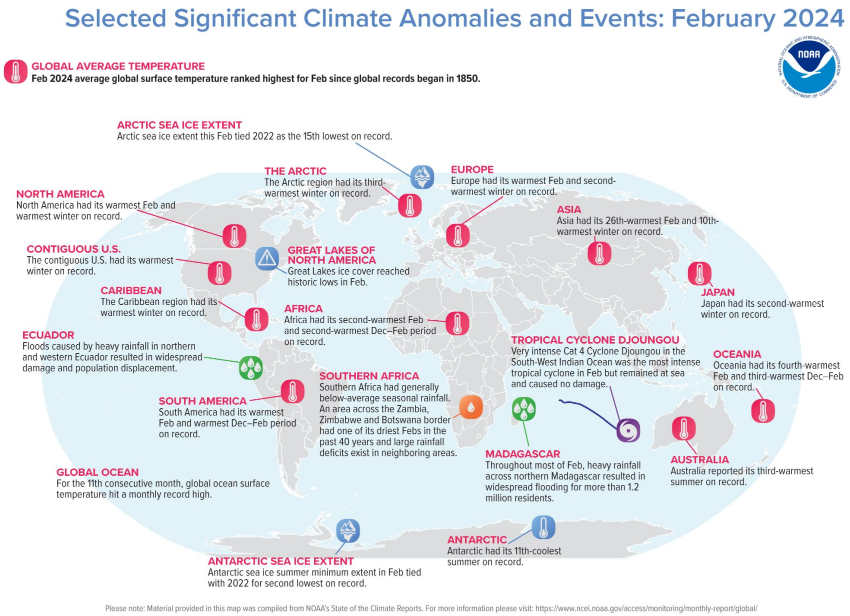
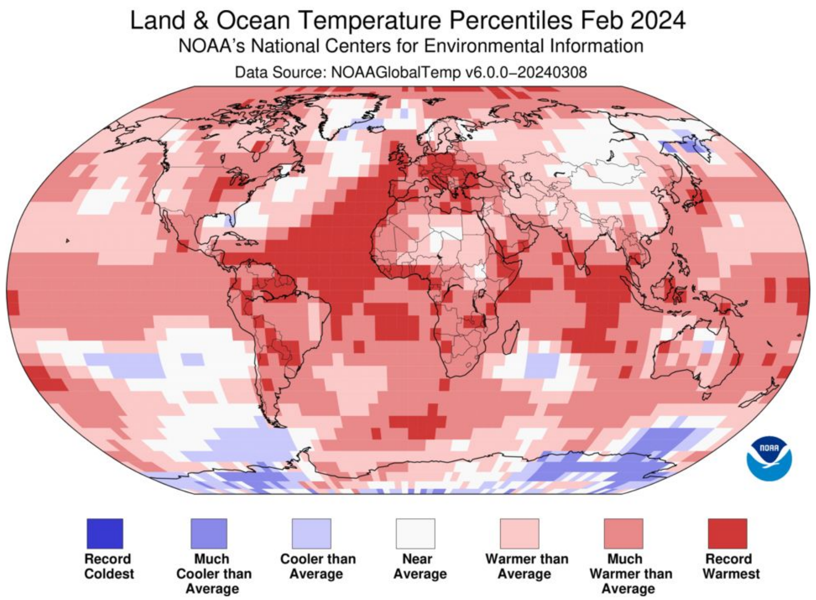
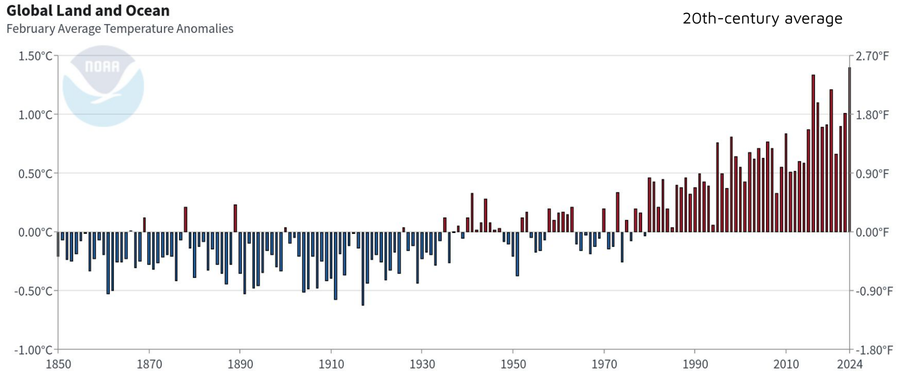
National Oceanic and Atmospheric Administration
U.S. Department of Commerce







https://www.ncdc.noaa.gov/sotc/global/

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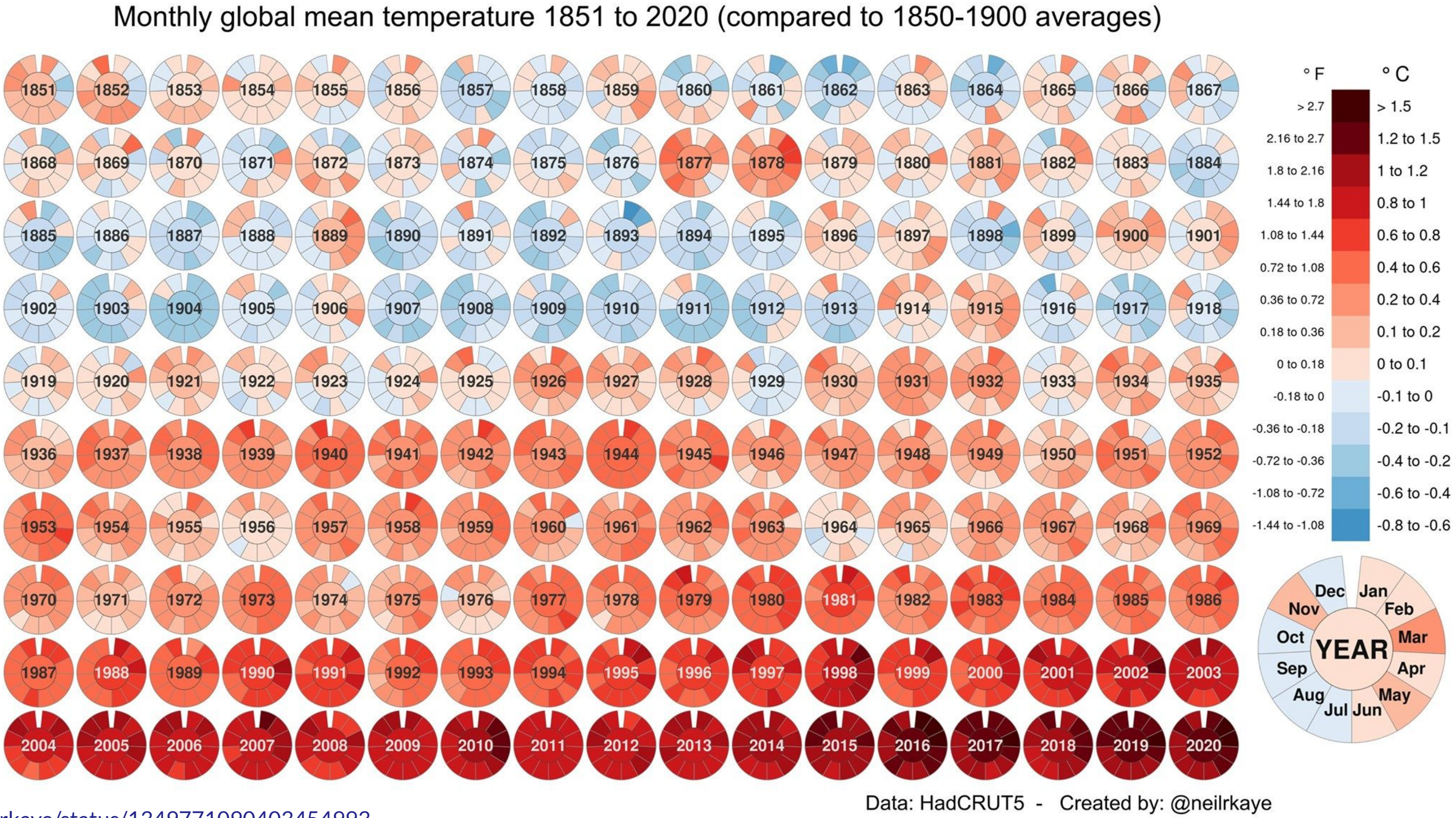

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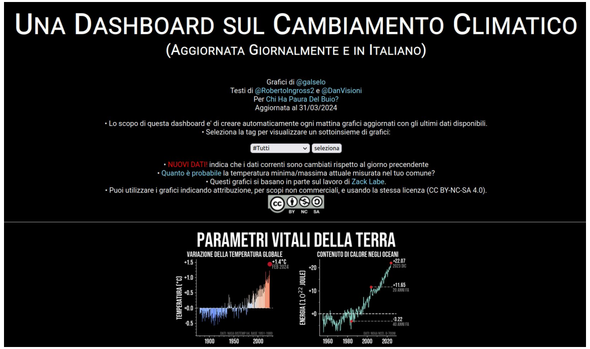
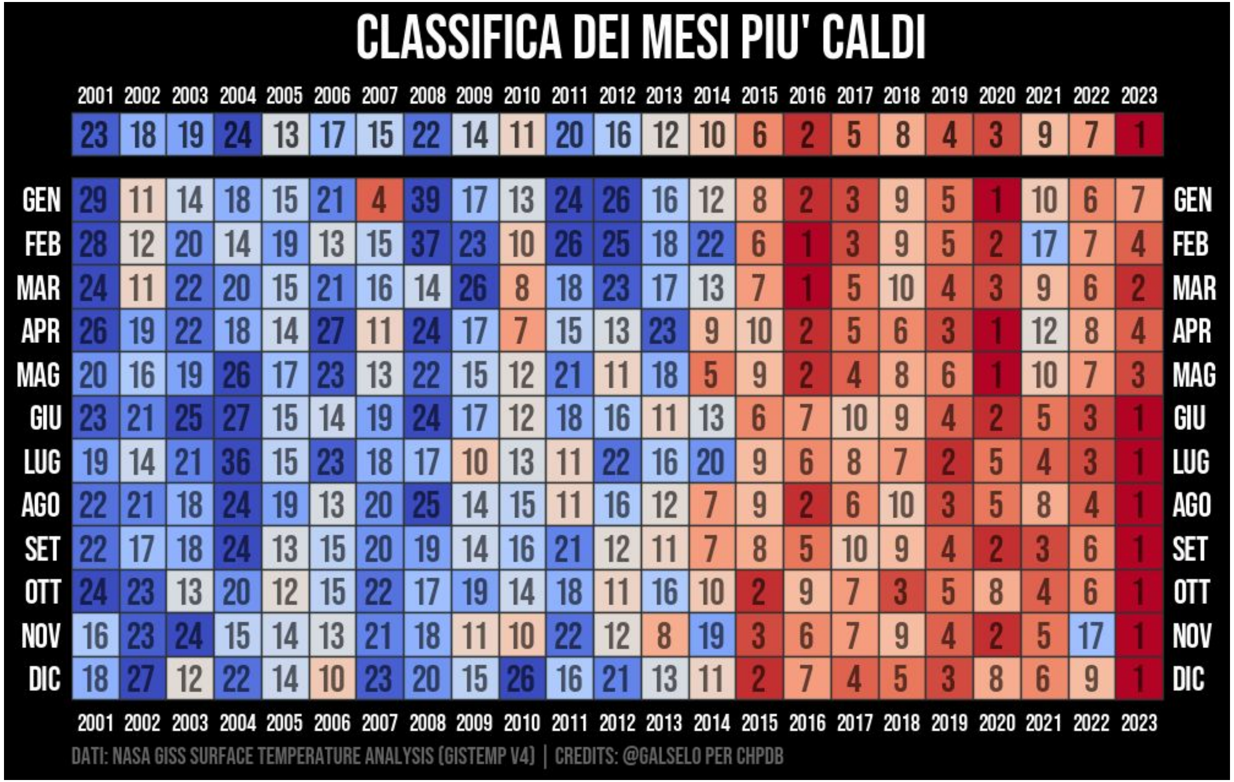
https://chpdb.it/_climate_dash/





CLASSIFICA DEI MESI PIU' CALDI

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
	23	18	19	24	13	17	15	22	14	11	20	16	12	10	6	2	5	8	4	3	9	7	1
GEN	29	11	14	18	15	21	4	39	17	13	24	26	16	12	8	2	3	9	5	1	10	6	7
FEB	28	12	20	14	19	13	15	37	23	10	26	25	18	22	6	1	3	9	5	2	17	7	4
MAR	24	11	22	20	15	21	16	14	26	8	18	23	17	13	7	1	5	10	4	3	9	6	2
APR	26	19	22	18	14	27	11	24	17	7	15	13	23	9	10	2	5	6	3	1	12	8	4
MAG	20	16	19	26	17	23	13	22	15	12	21	11	18	5	9	2	4	8	6	1	10	7	3
GIU	23	21	25	27	15	14	19	24	17	12	18	16	11	13	6	7	10	9	4	2	5	3	1
LUG	19	14	21	36	15	23	18	17	10	13	11	22	16	20	9	6	8	7	2	5	4	3	1
AGO	22	21	18	24	19	13	20	25	14	15	11	16	12	7	9	2	6	10	3	5	8	4	1
SET	22	17	18	24	13	15	20	19	14	16	21	12	11	7	8	5	10	9	4	2	3	6	1
OTT	24	23	13	20	12	15	22	17	19	14	18	11	16	10	2	9	7	3	5	8	4	6	1
NOV	16	23	24	15	14	13	21	18	11	10	22	12	8	19	3	6	7	9	4	2	5	17	1
DIC	18	27	12	22	14	10	23	20	15	26	16	21	13	11	2	7	4	5	3	8	6	9	1

DATI: NASA GISS SURFACE TEMPERATURE ANALYSIS (GISTEMP V4) | CREDITS: @GALSELO PER CHPDB

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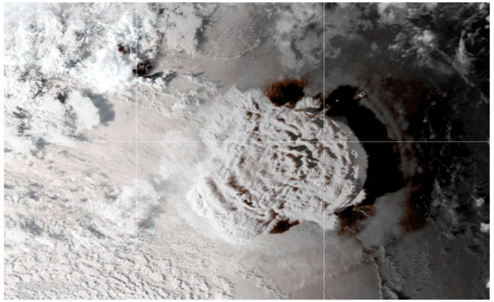
https://chpdb.it/_climate_dash/

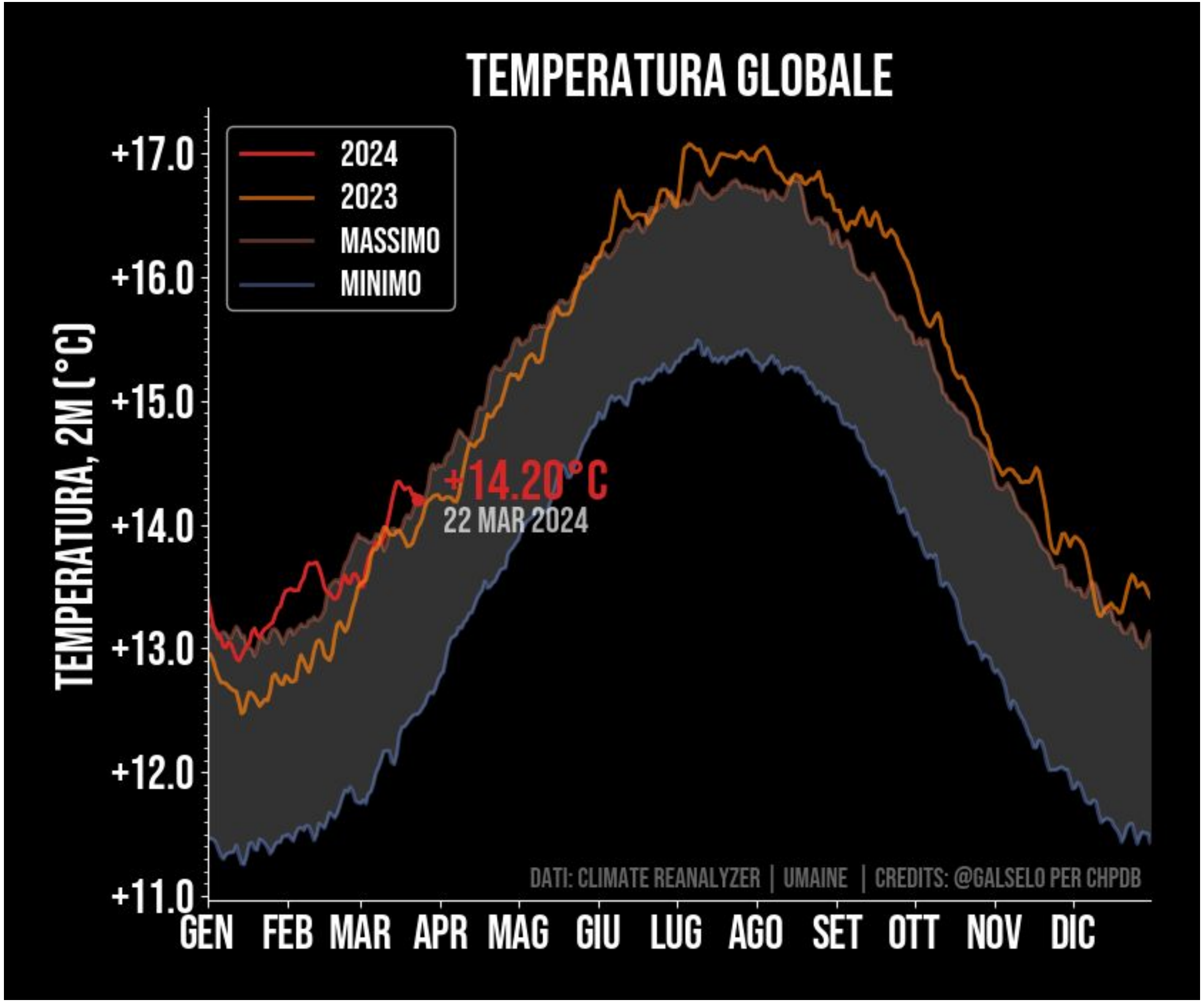
December 2023 El Niño update: adventure!

BY EMILY BECKER
PUBLISHED DECEMBER 13, 2023
COMMENTS: 34

El Niño is zipping along in the tropical Pacific. There's a 54% chance that this El Niño event will end up "historically strong" (more details below), potentially ranking in the top 5 on record. Looking ahead, it's likely that El Niño will end and neutral conditions return by April–June.

Tonga Eruption Blasted Unprecedented Amount of Water Into Stratosphere



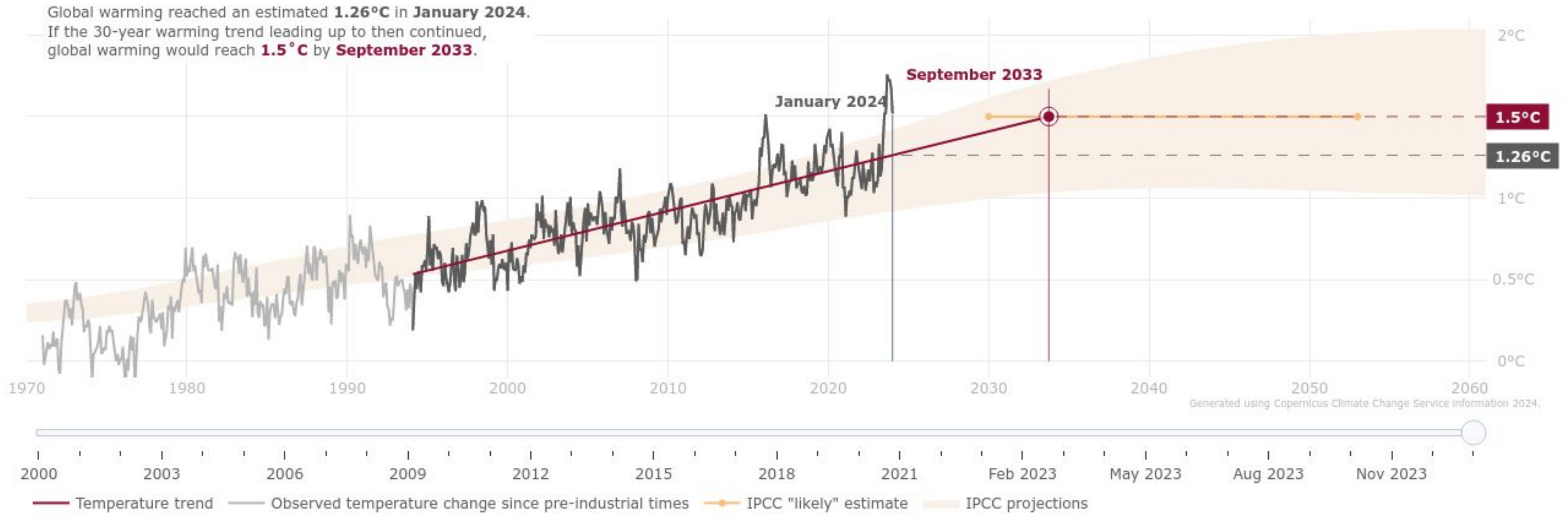


https://climate.copernicus.eu/

How close are we to reaching a global warming of 1.5˚C?

Reaching 1.5˚C of global warming - a limit agreed under the Paris agreement - may feel like a very distant reality, but it might be closer than you think. Experts suggest it is likely to happen between 2030 and the early 2050s. See where we are now and how soon we would reach the limit if the warming continued at today's pace. **Use the slider to explore how the estimate changes in time.**

Explore the app in the CDS



Version: 4.35.4 - build f8ced5bb

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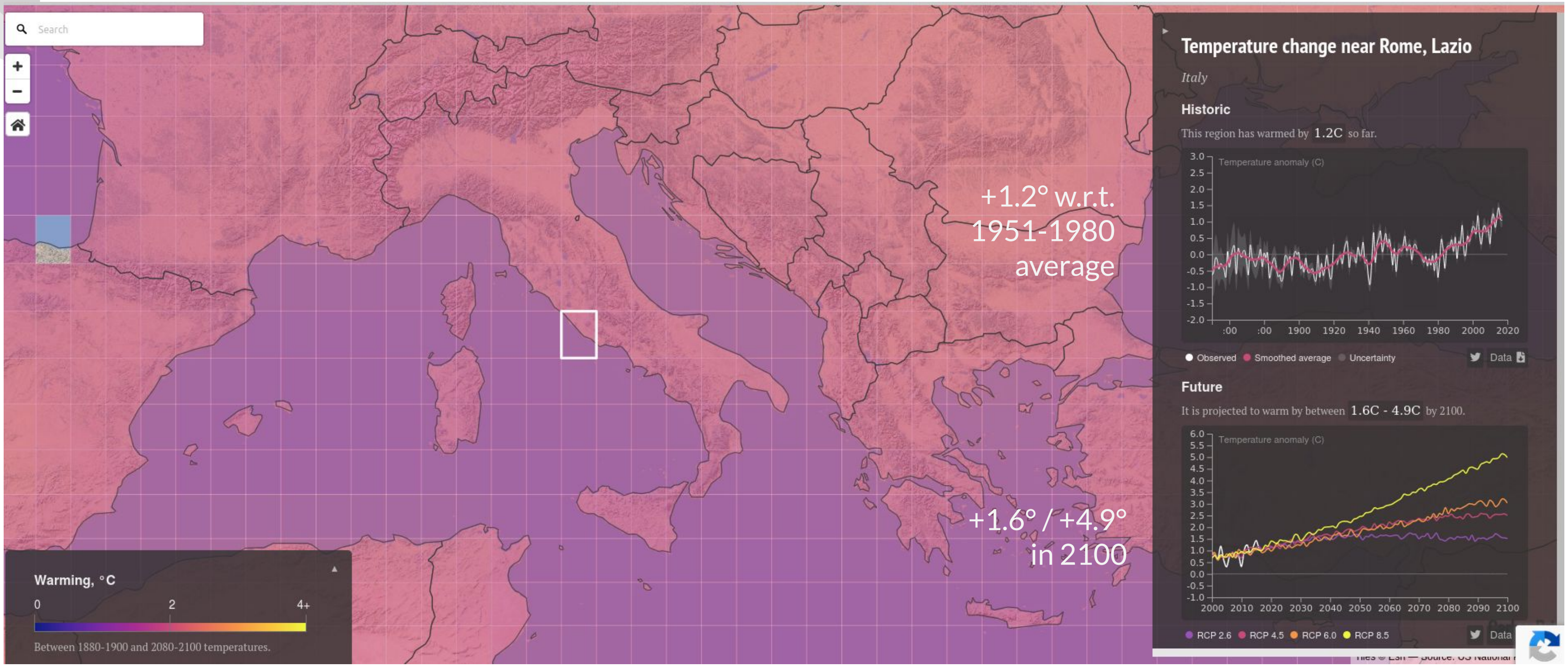

RCPs
(Representative
Concentration
Pathways)

https://www.carbonbrief.org/mapped-how-every-part-of-the-world-has-warmed-and-could-continue-to-warm

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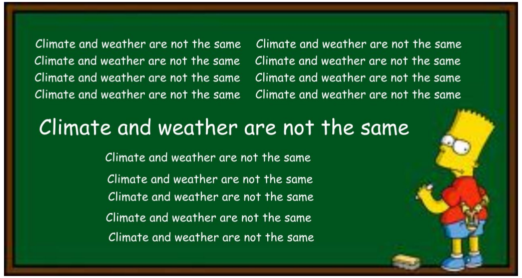

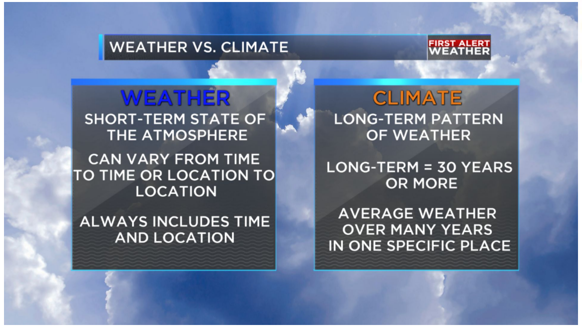

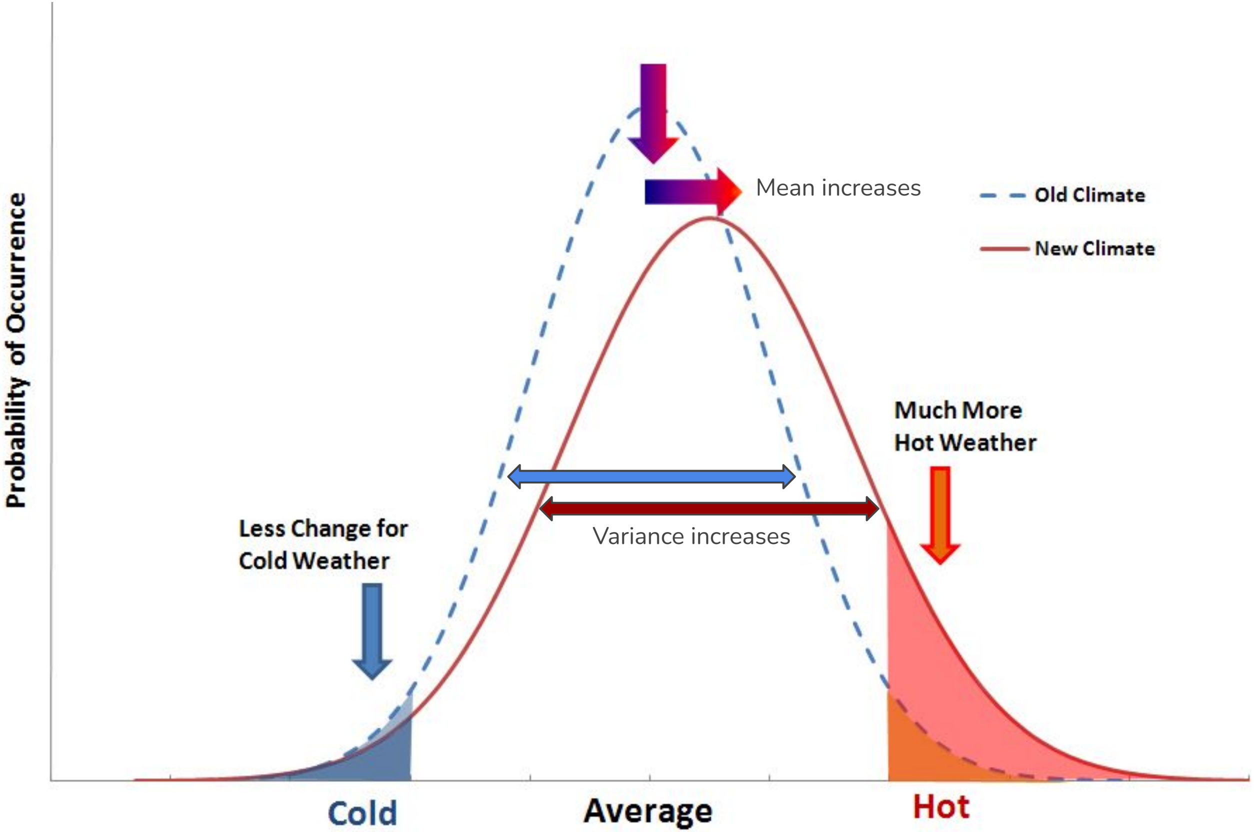

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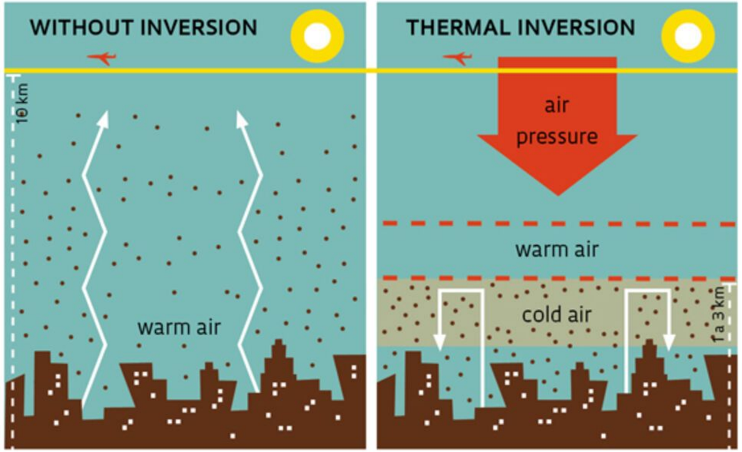
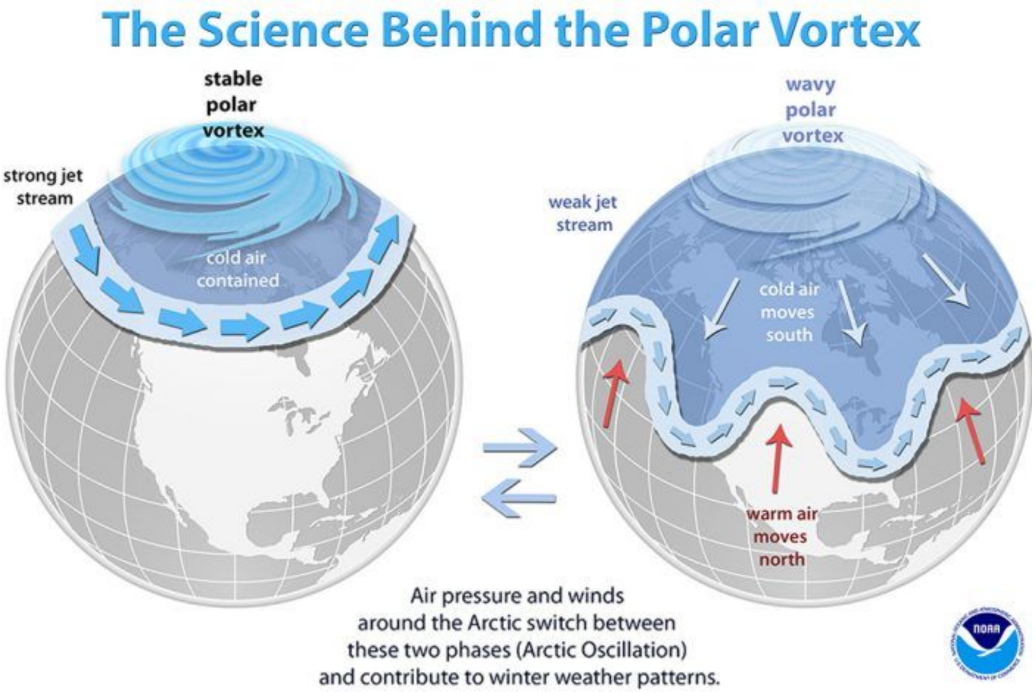
But it’s freezing outside!





National Oceanic and Atmospheric Administration
U.S. Department of Commerce

https://www.noaa.gov/multimedia/infographic/science-behind-polar-vortex

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In the middle ages it was hotter than now! (a.k.a. “the warm medieval period”)

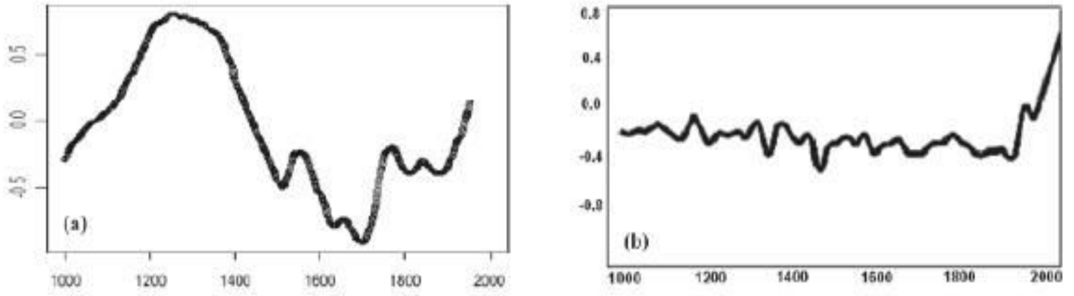
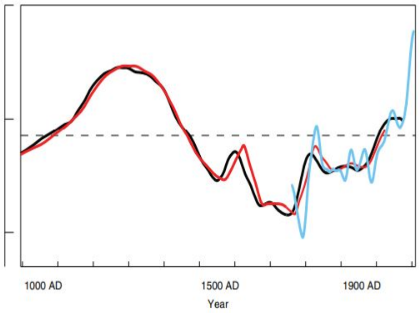


Fig. 2 - Andamento delle temperature globali secondo il report IPCC del 1990 (a) e del 2001 (b). Il grafico (b) è noto come hockey stick ed è frutto del lavoro di MANN *et alii* (1998). Si noti la potenza dell'optimum climatico medioevale e della piccola era glaciale secondo la curva (a) e la loro sostanziale scomparsa nella curva (b)

Crescenti+2010

High-resolution palaeoclimatology of the last millennium: a review of current status and future prospects

P.D. Jones,[1]* K.R. Briffa,[1] T.J. Osborn,[1] J.M. Lough,[2] T.D. van Ommen,[3] B.M. Vinther,[4] J. Luterbacher,[5] E.R. Wahl,[6] F.W. Zwiers,[7] M.E. Mann,[8] G.A. Schmidt,[9] C.M. Ammann,[10] B.M. Buckley,[11] K.M. Cobb,[12] J. Esper,[13] H. Goosse,[14] N. Graham,[15] E. Jansen,[16] T. Kiefer,[17] C. Kull,[18] M. Küttel,[5] E. Mosley-Thompson,[19] J.T. Overpeck,[20] N. Riedwyl,[5] M. Schulz,[21] A.W. Tudhope,[22] R. Villalba,[23] H. Wanner,[5] E. Wolff[24] and E. Xoplaki[5]



In summary, we show that the curve used by IPCC (1990) was locally representative (nominally of Central England) and not global, and was referred to at the time with the word ‘schematic’.

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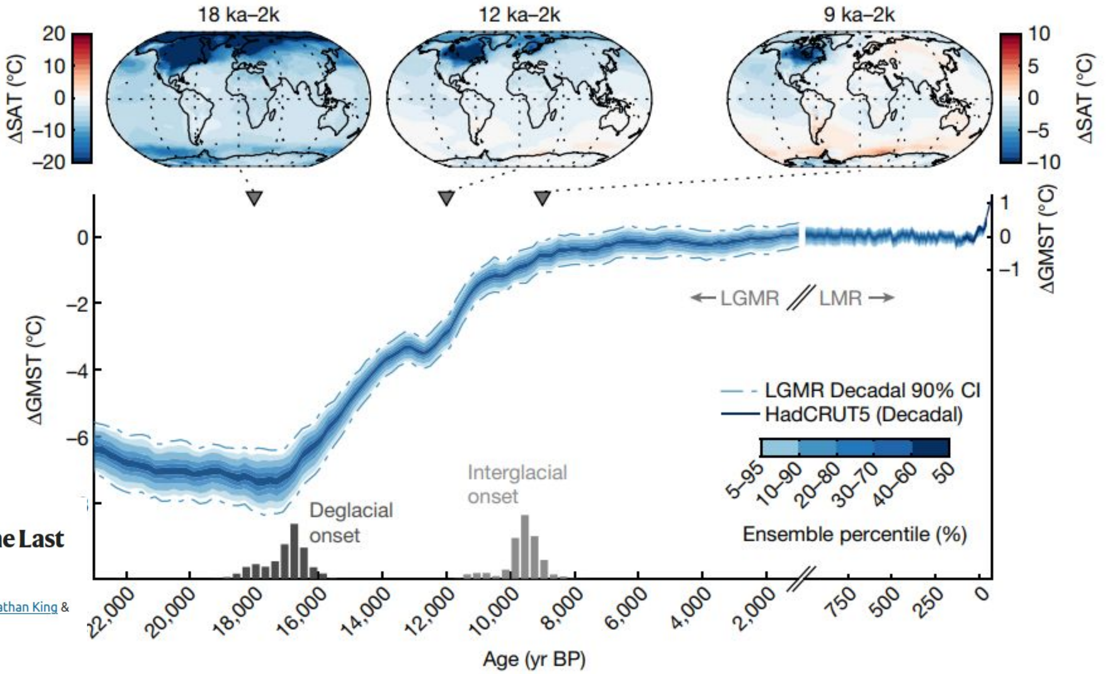
Climate has been changing since forever!



Article | Published: 10 November 2021

Globally resolved surface temperatures since the Last Glacial Maximum

Matthew B. Osman, Jessica E. Tierney, Jiang Zhu, Robert Tardif, Gregory J. Hakim, Jonathan King & Christopher J. Poulsen

Nature **599**, 239–244 (2021) | Cite this article

Fig. 2 | Global mean surface temperature change over the past 24 kyr. Ensemble distribution ($n = 500$ posterior means) of LGMR GMST for the past 24 kyr (blue colours), with a decadal 90th-percentile range (dotted-dashed lines) estimated using decadal-to-centennial variance ratios from iCESM (Methods). Shown at the top are spatial surface air temperature (SAT) anomalies relative to the past two millennia ('2k', 0–2 ka) for intervals discussed in the main text. The estimated last deglacial and interglacial onset timings are shown as dark and light histograms at the bottom (Supplementary Information). Reconstructed decadal GMST from the last millennium reanalysis v2.1 (ref. [17]) and HadCRUT5 observational product[11] are plotted to the right of the LGMR. ΔGMST is computed relative to the preindustrial last millennium average (1000–1850 CE).

https://www.nature.com/articles/s41586-021-03984-4

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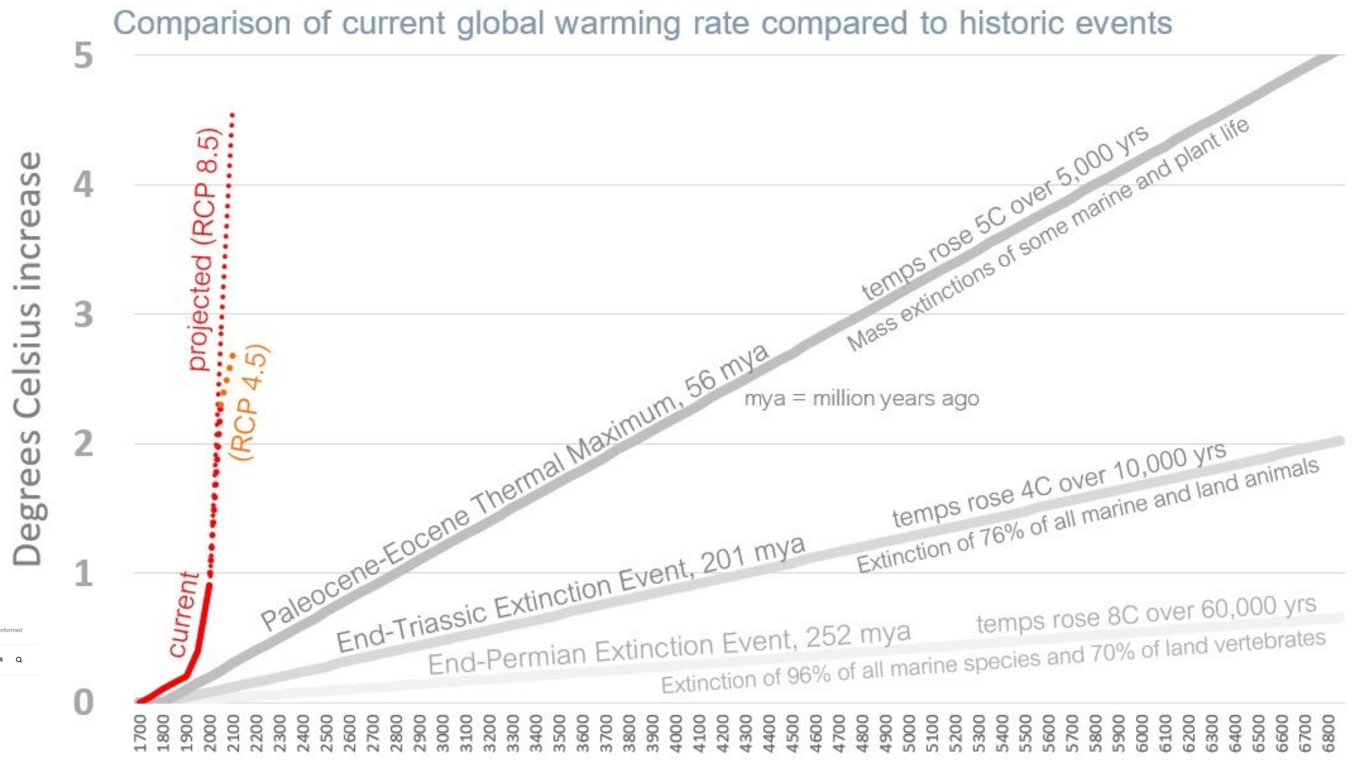
Climate has been changing since forever!

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Mass Extinctions Tied to Past Climate Changes

Fossil and temperature records over the past 520 million years show a correlation between extinctions and climate change

By David Biello on October 24, 2007

https://thecottonwoodpost.net/2019/12/10/modern-climate-change-is-10x-faster-than-historic-global-warming-mass-extinction-events/

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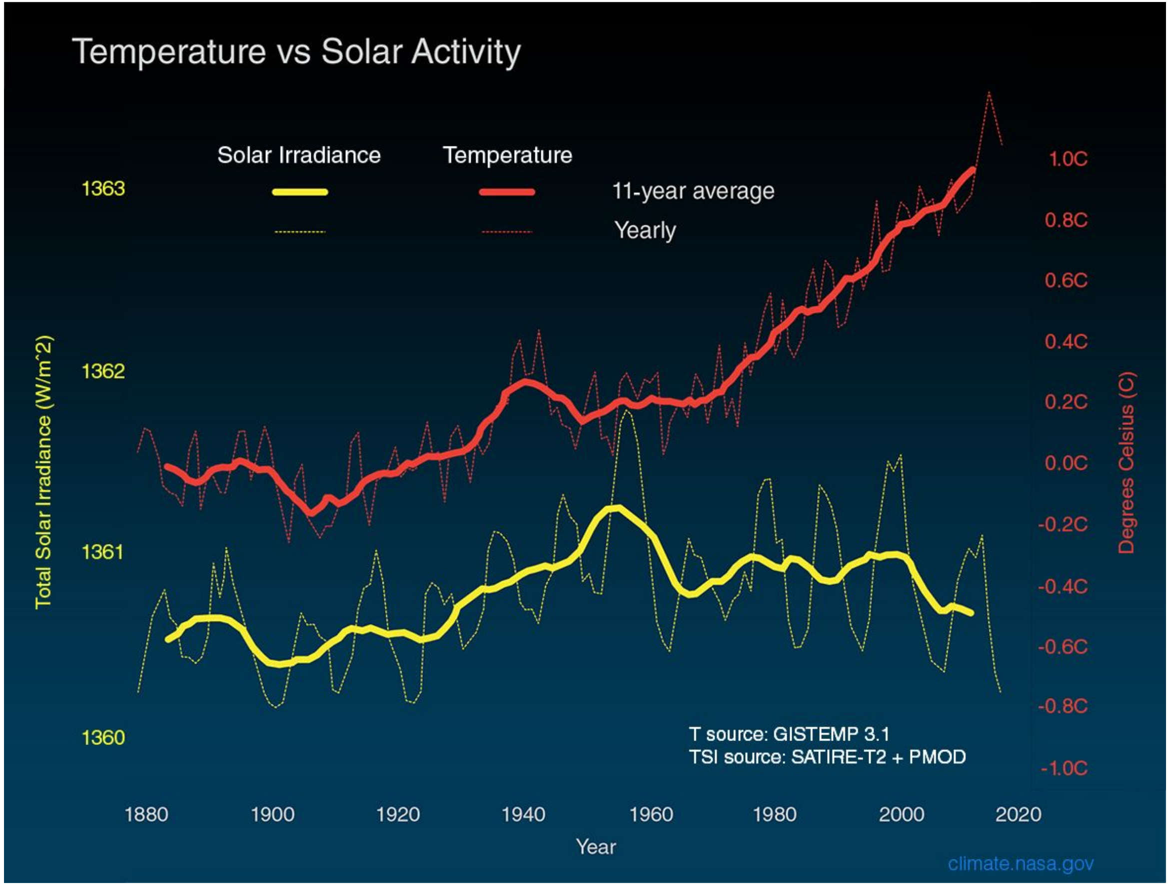
Ok it’s getting hotter, but it’s just solar activity!



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Climate models

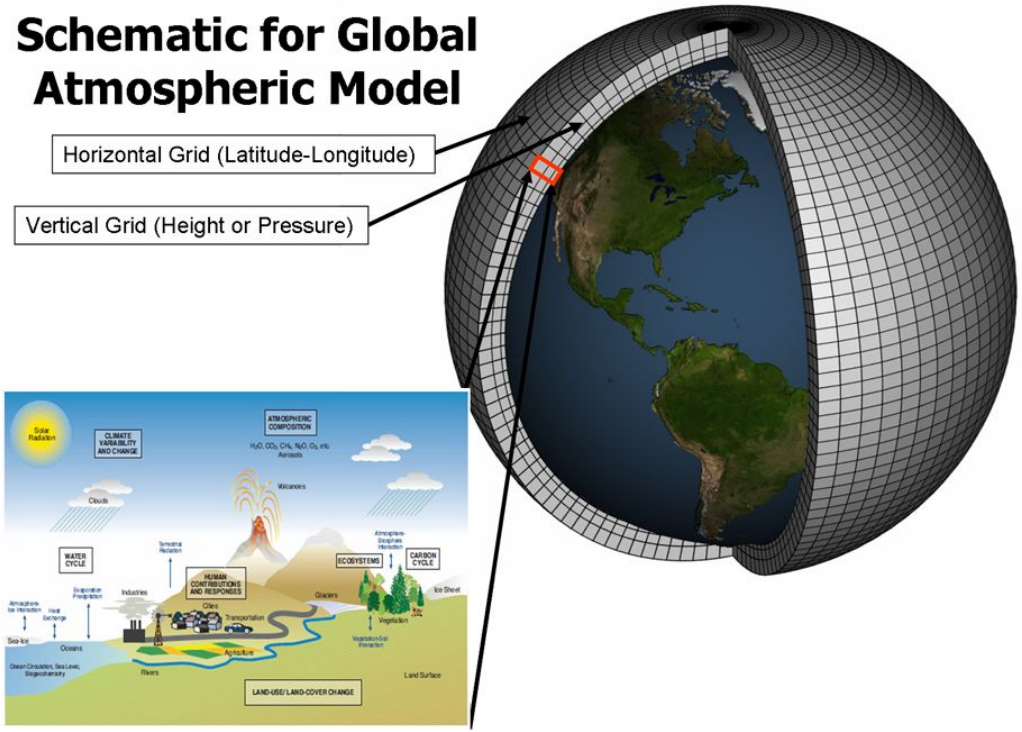
$$\frac{\partial \mathbf{u}}{\partial t} = -(\mathbf{u}\cdot\nabla)\mathbf{u} + \nabla\cdot(\upsilon\nabla\mathbf{u}) - \frac{1}{\rho}\nabla p + \mathbf{f}$$

kinematic viscosity (constant)
density (constant)
pressure
external force (such as gravity)

Navier-Stokes
Clausius-Clapeyron
Stefan-Boltzmann

$$P = \varepsilon\sigma A T^4$$

$$\ln\frac{P_1}{P_2} = \frac{\Delta H_{vap}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$



https://www.carbonbrief.org/qa-how-do-climate-models-work

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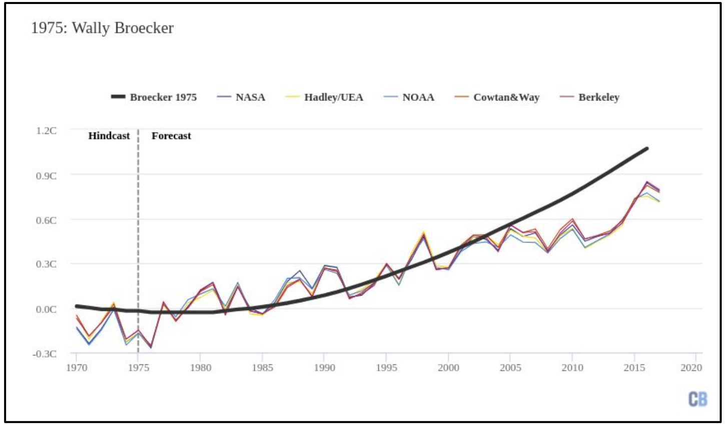

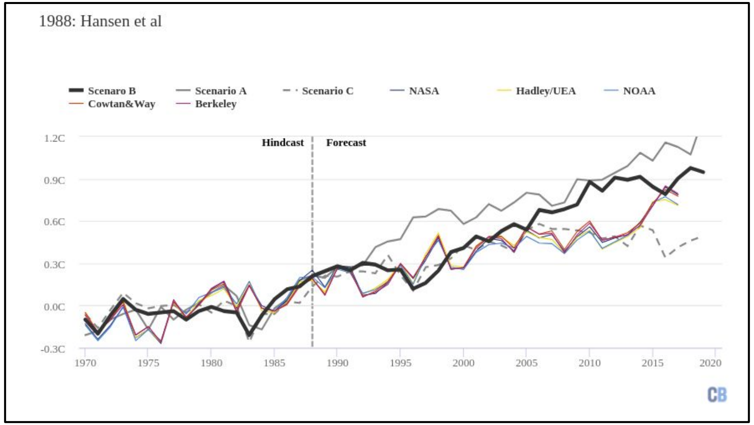

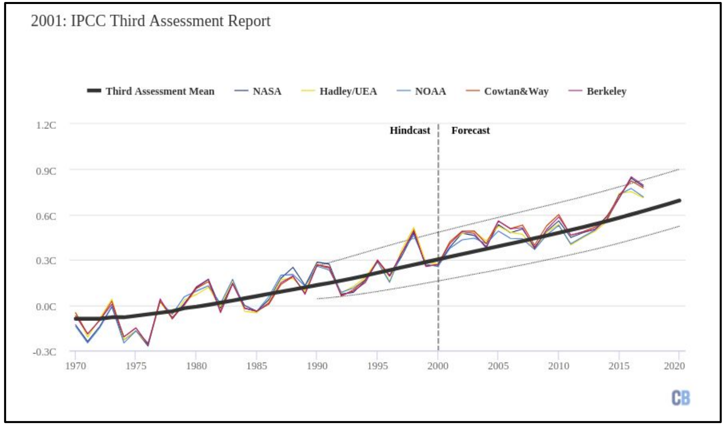

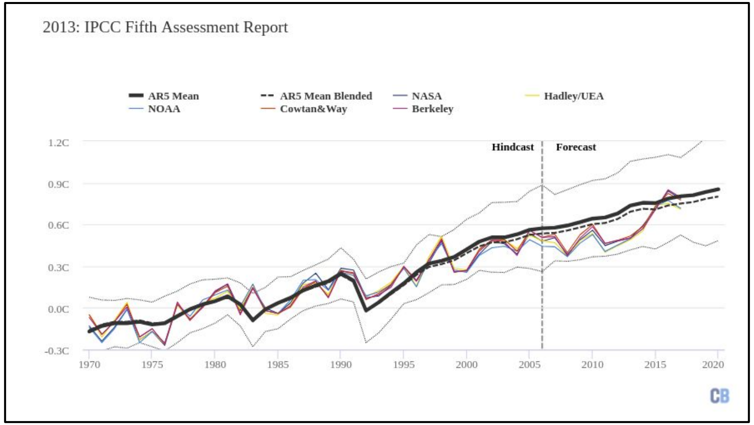

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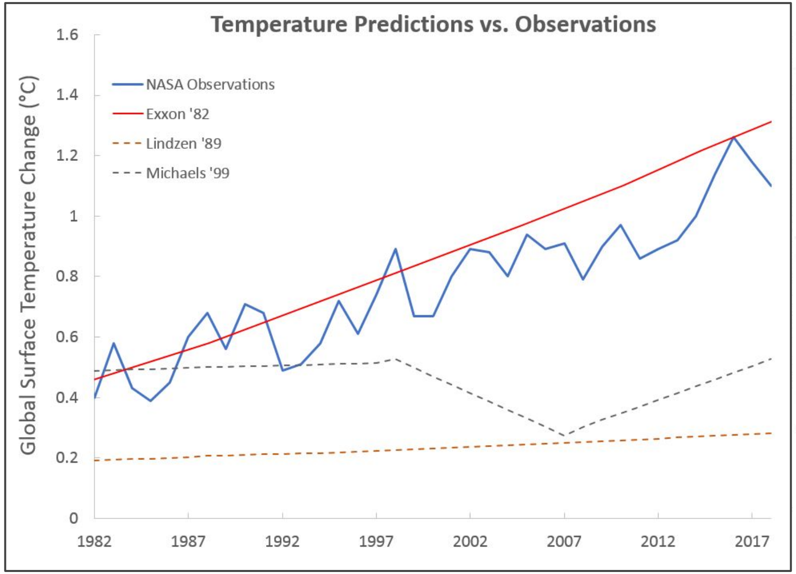

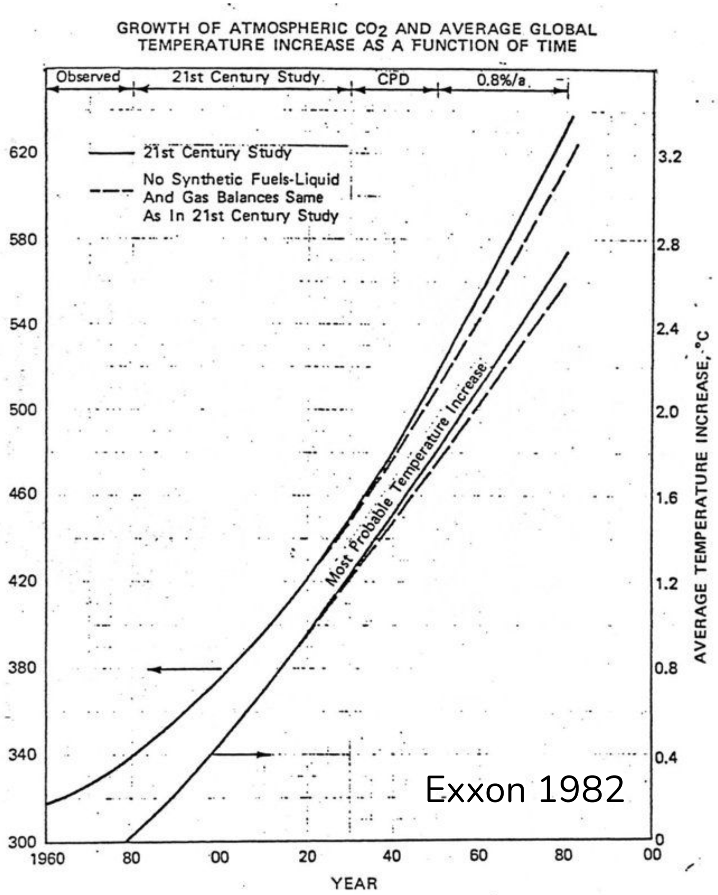

https://insideclimatenews.org/sites/default/files/documents/1982%20Exxon%20Primer%20on%20CO2%20Greenhouse%20Effect.pdf

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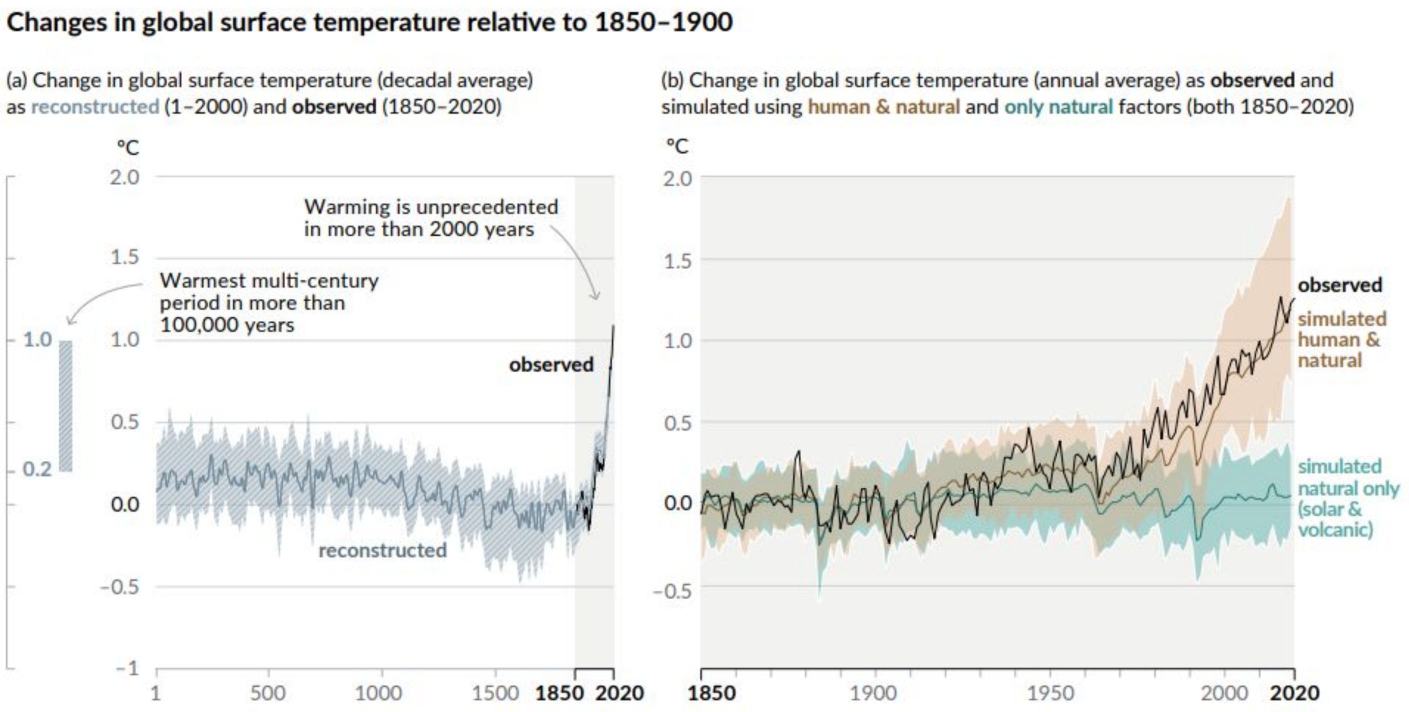
Human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years



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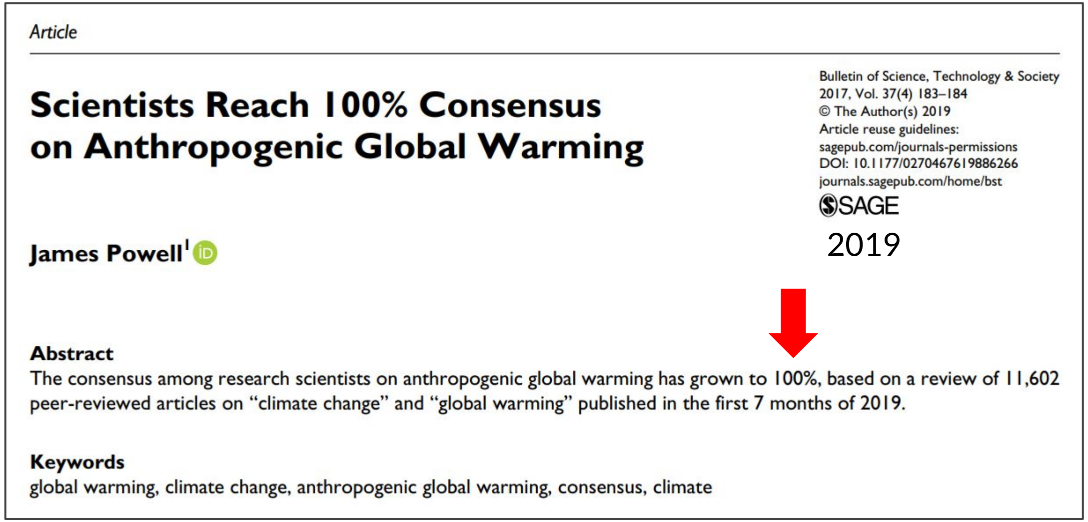
Scientific consensus is ~100%


Article

Scientists Reach 100% Consensus on Anthropogenic Global Warming

Bulletin of Science, Technology & Society
2017, Vol. 37(4) 183–184

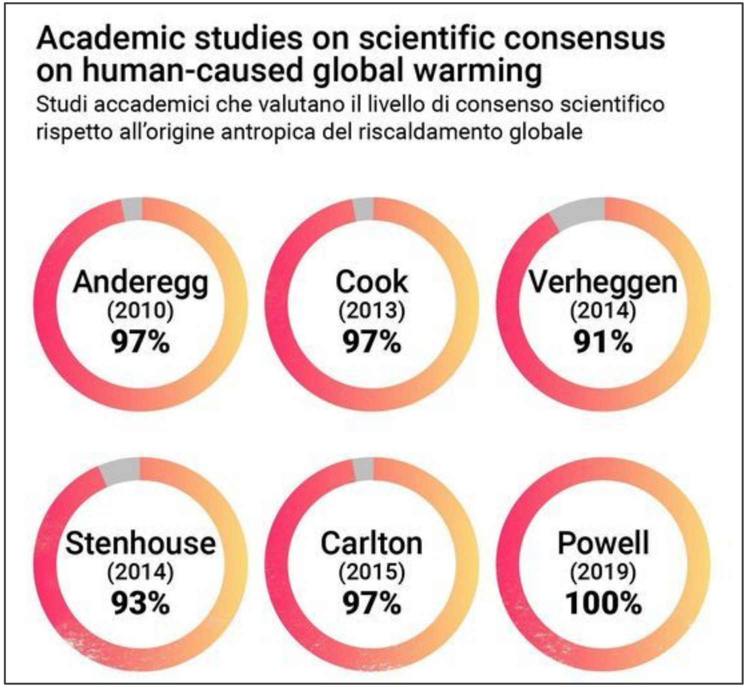
DOI: 10.1177/0270467619886266
journals.sagepub.com/home/bst
SAGE

2019

James Powell[1]

Abstract
The consensus among research scientists on anthropogenic global warming has grown to 100%, based on a review of 11,602 peer-reviewed articles on "climate change" and "global warming" published in the first 7 months of 2019.

Keywords
global warming, climate change, anthropogenic global warming, consensus, climate



https://weather.com/science/environment/news/americans-climate-change-scientific-consensus

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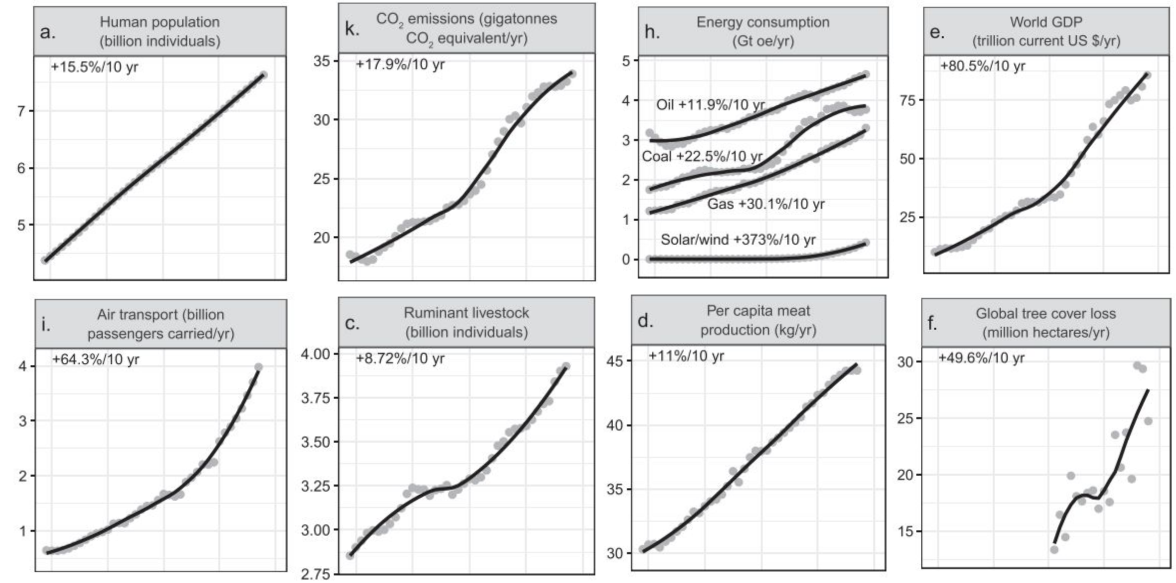
Scientific consensus

World Scientists' Warning of a Climate Emergency

WILLIAM J. RIPPLE, CHRISTOPHER WOLF, THOMAS M. NEWSOME, PHOEBE BARNARD, WILLIAM R. MOOMAW, AND 11,258 SCIENTIST SIGNATORIES FROM 153 COUNTRIES (LIST IN SUPPLEMENTAL FILE S1)

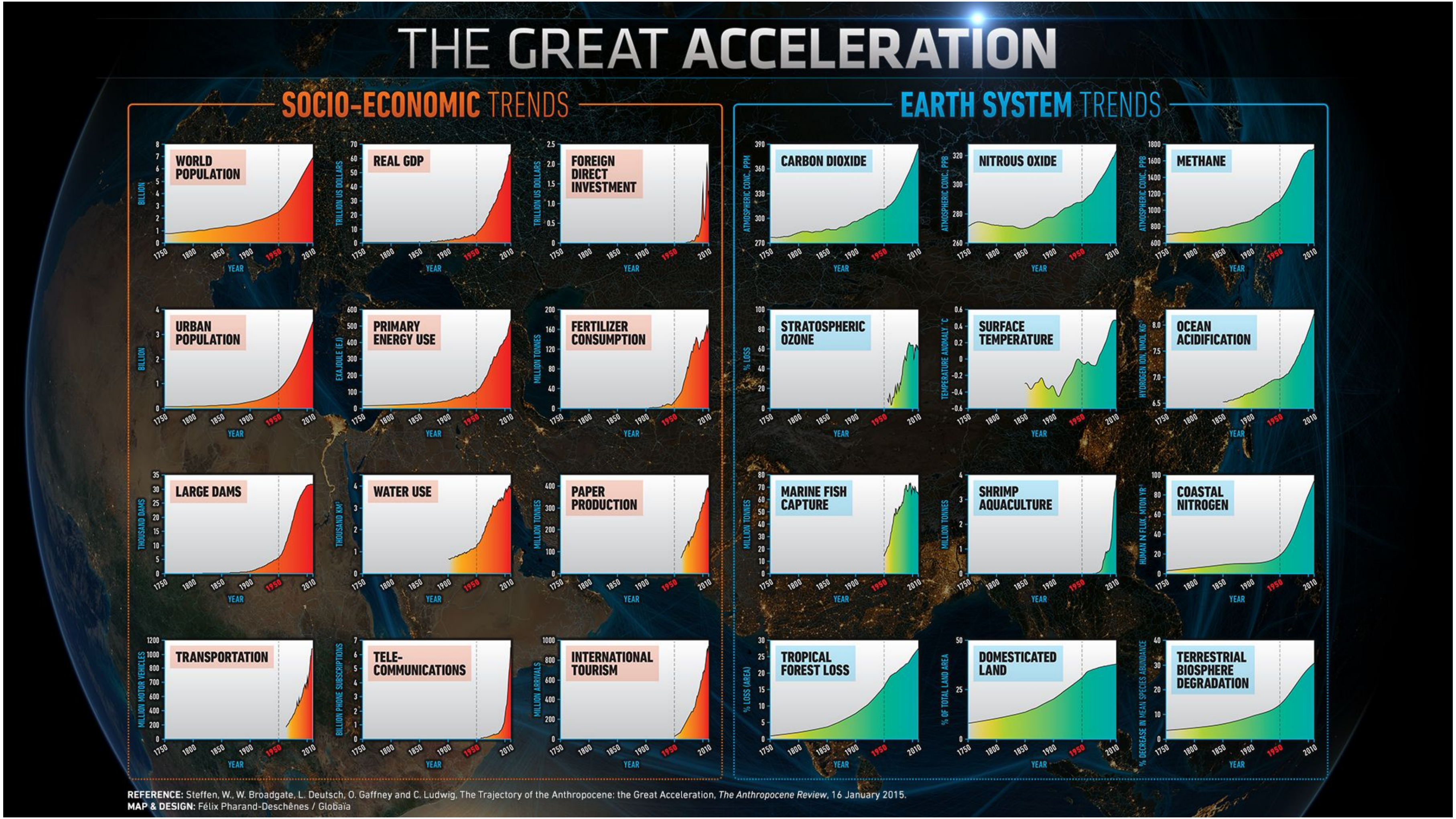
Scientists have a moral obligation to clearly warn humanity of any catastrophic threat and to "tell it like it is." On the basis of this obligation and the graphical indicators presented below, we declare, with more than 11,000 scientist signatories from around the world, clearly and unequivocally that planet Earth is facing a climate emergency.

Most public discussions on climate change are based on global surface temperature only, an inadequate measure to capture the breadth of human activities and the real dangers stemming from a warming planet (Briggs et al. 2015). Policymakers and the public now urgently need access to a set of indicators that convey the effects of human activities on GHG emissions and the consequent impacts on climate, our environment, and society.



1979-2019

https://academic.oup.com/bioscience/advance-article/doi/10.1093/biosci/biz088/5610806


THE GREAT ACCELERATION
SOCIO-ECONOMIC TRENDS
EARTH SYSTEM TRENDS
WORLD POPULATION
BILLION
REAL GDP
TRILLION US DOLLARS
FOREIGN DIRECT INVESTMENT
TRILLION US DOLLARS
URBAN POPULATION
BILLION
PRIMARY ENERGY USE
EXAJOULE (EJ)
FERTILIZER CONSUMPTION
MILLION TONNES
LARGE DAMS
THOUSAND DAMS
WATER USE
THOUSAND KM³
PAPER PRODUCTION
MILLION TONNES
TRANSPORTATION
MILLION MOTOR VEHICLES
TELE-COMMUNICATIONS
BILLION PHONE SUBSCRIPTIONS
INTERNATIONAL TOURISM
MILLION ARRIVALS
CARBON DIOXIDE
ATMOSPHERIC CONC., PPM
NITROUS OXIDE
ATMOSPHERIC CONC., PPB
METHANE
ATMOSPHERIC CONC., PPB
STRATOSPHERIC OZONE
% LOSS
SURFACE TEMPERATURE
TEMPERATURE ANOMALY °C
OCEAN ACIDIFICATION
HYDROGEN ION, NMOL KG⁻¹
MARINE FISH CAPTURE
MILLION TONNES
SHRIMP AQUACULTURE
MILLION TONNES
COASTAL NITROGEN
HUMAN N FLUX, MTON YR⁻¹
TROPICAL FOREST LOSS
% LOSS (AREA)
DOMESTICATED LAND
% OF TOTAL LAND AREA
TERRESTRIAL BIOSPHERE DEGRADATION
% DECREASE IN MEAN SPECIES ABUNDANCE
YEAR
1750 1800 1850 1900 1950 2010
REFERENCE: Steffen, W., W. Broadgate, L. Deutsch, O. Gaffney and C. Ludwig, The Trajectory of the Anthropocene: the Great Acceleration, The Anthropocene Review, 16 January 2015.
MAP & DESIGN: Félix Pharand-Deschênes / Globaïa

1. Is climate changing? Is it caused by human activities? Is this debated by experts?
2. Can we foresee the consequences of climate change?
3. Which are its physical causes?
4. Which human activities are more impactful?
5. What can/should we do?

Yes, yes, no.

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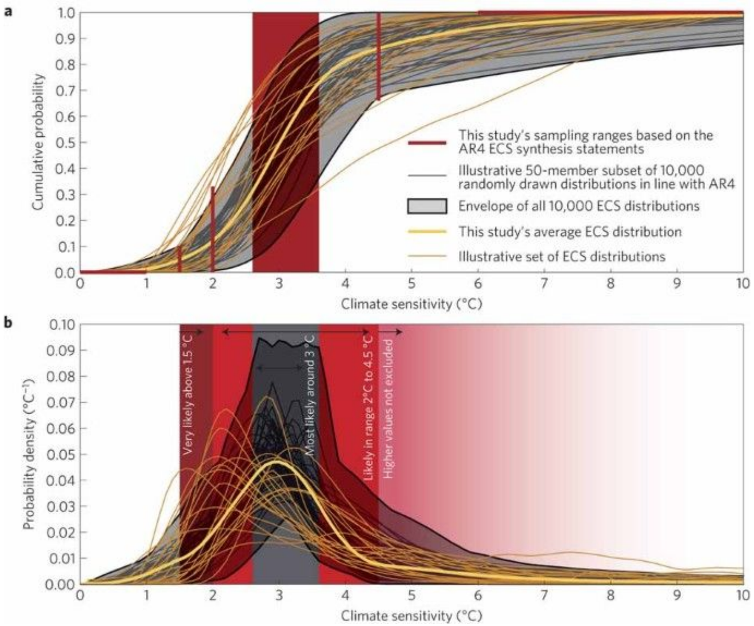
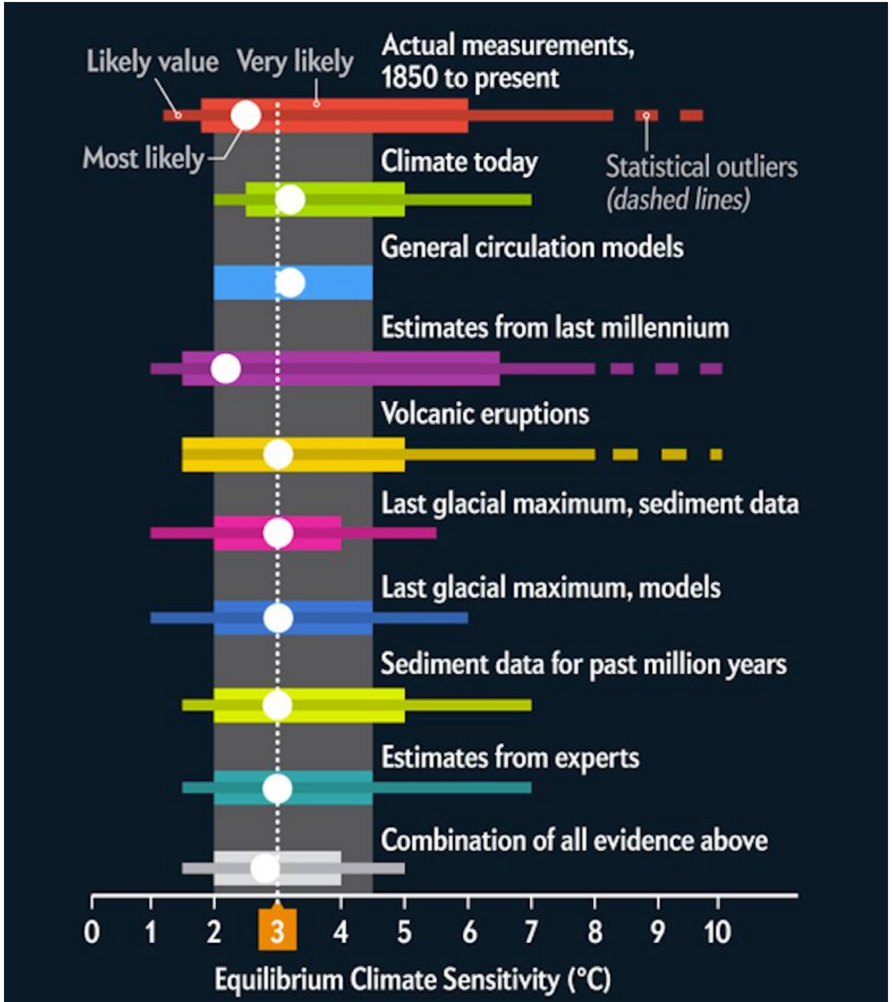
Forecasting requires good knowledge of:
1- **Climate sensitivity** (how much does doubling the amount of greenhouse gas actually warm the atmosphere?)
2- How does the warming impact the biosphere?

https://www.nature.com/articles/nclimate1385





https://michaelmann.net/content/sensitive-topic

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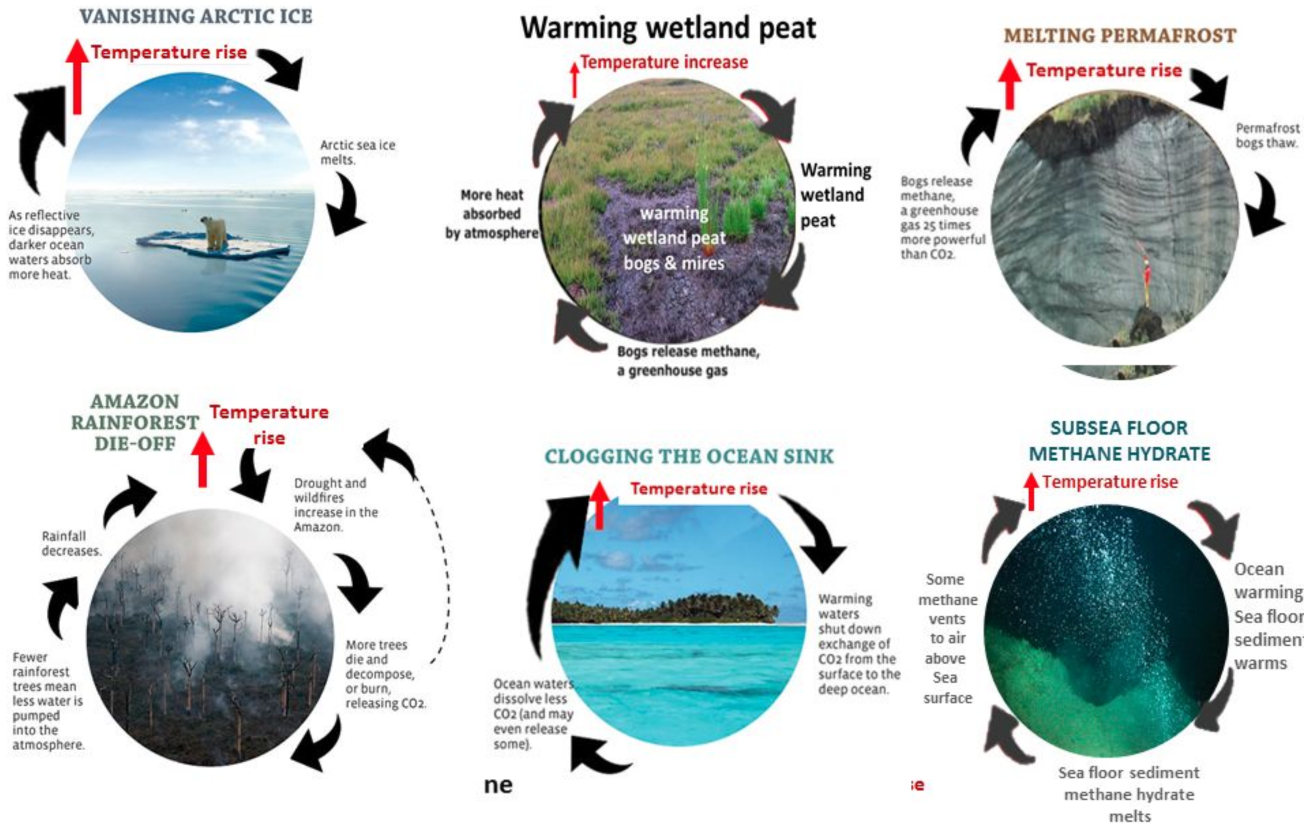
Feedback effects



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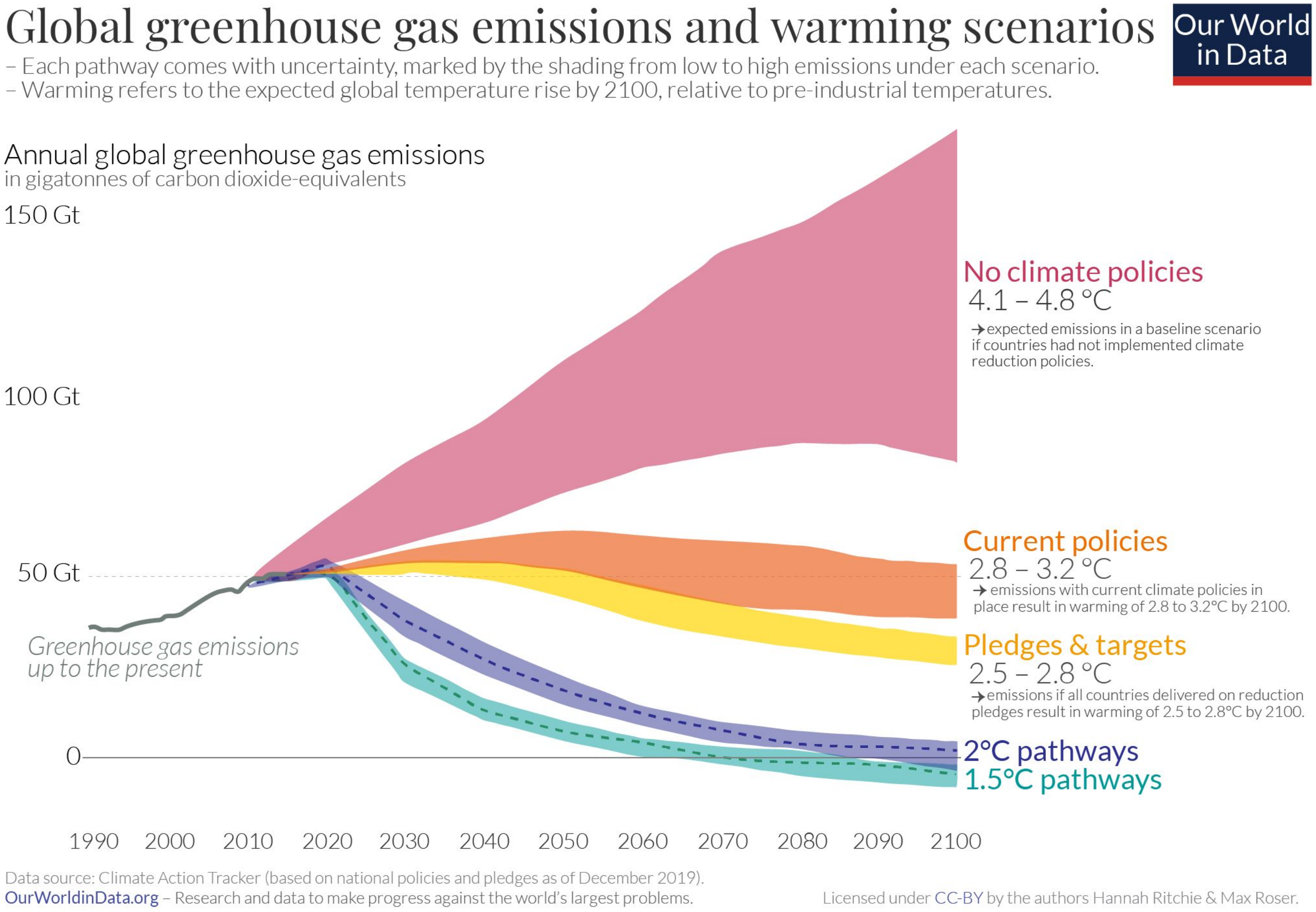

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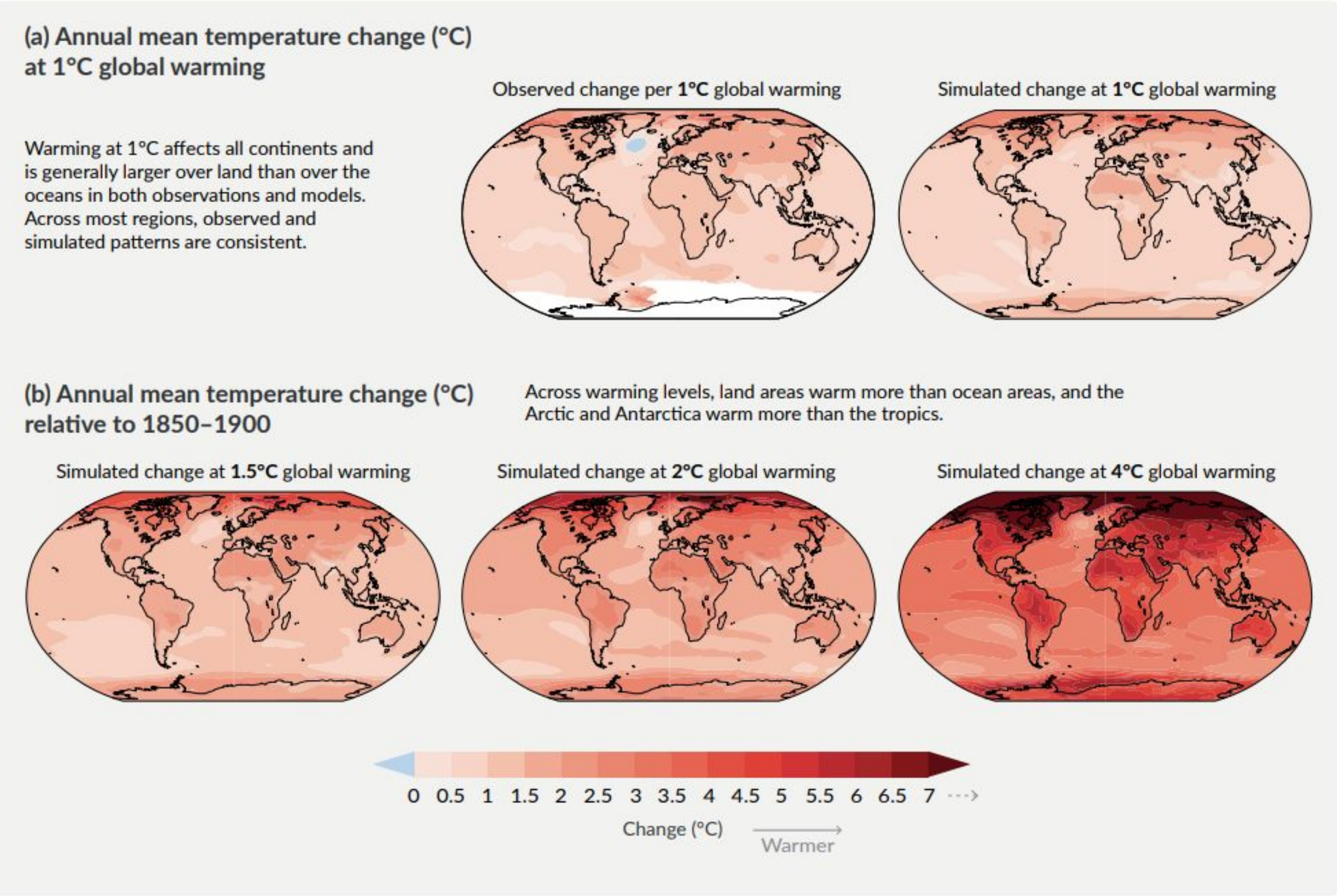

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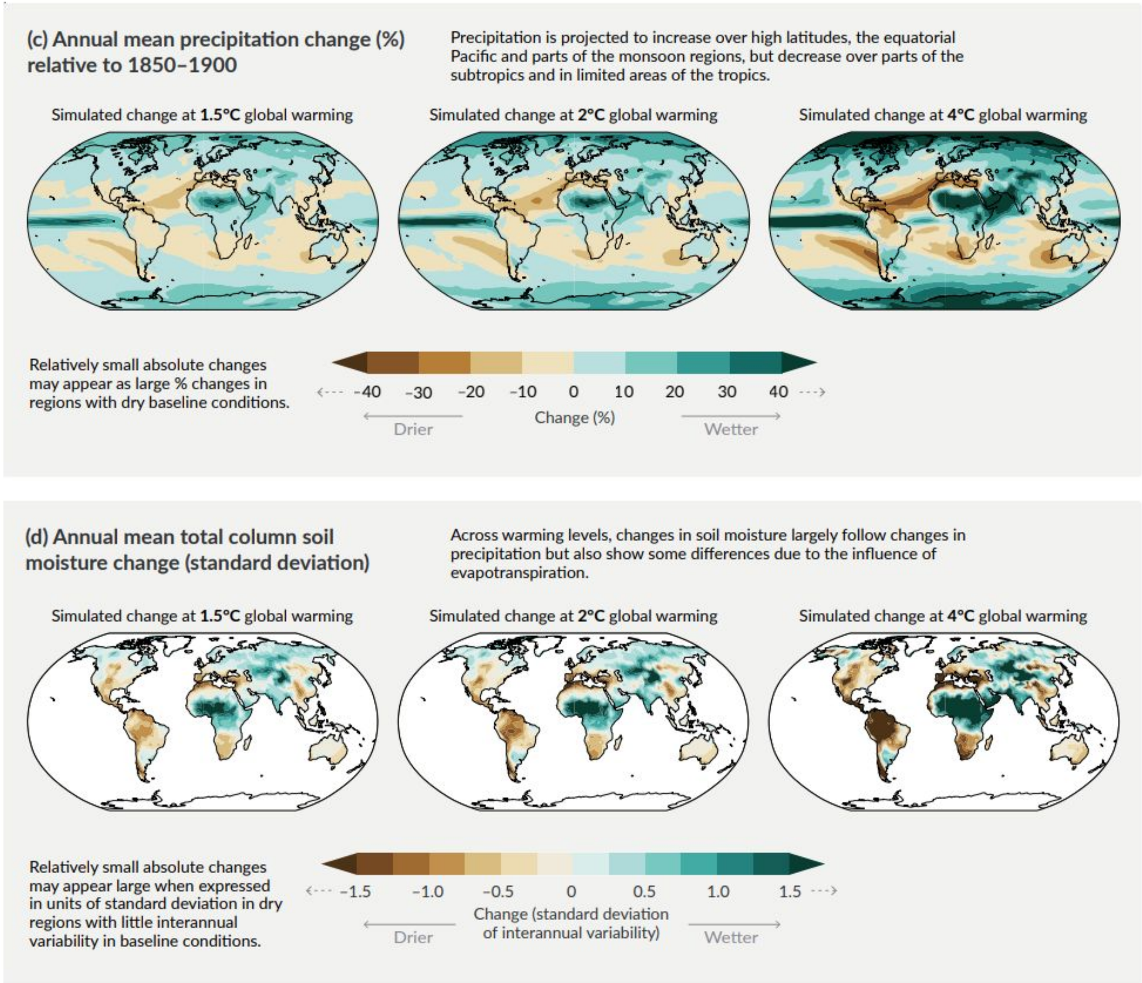

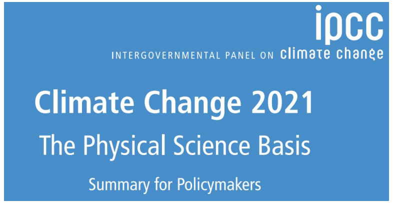

https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf

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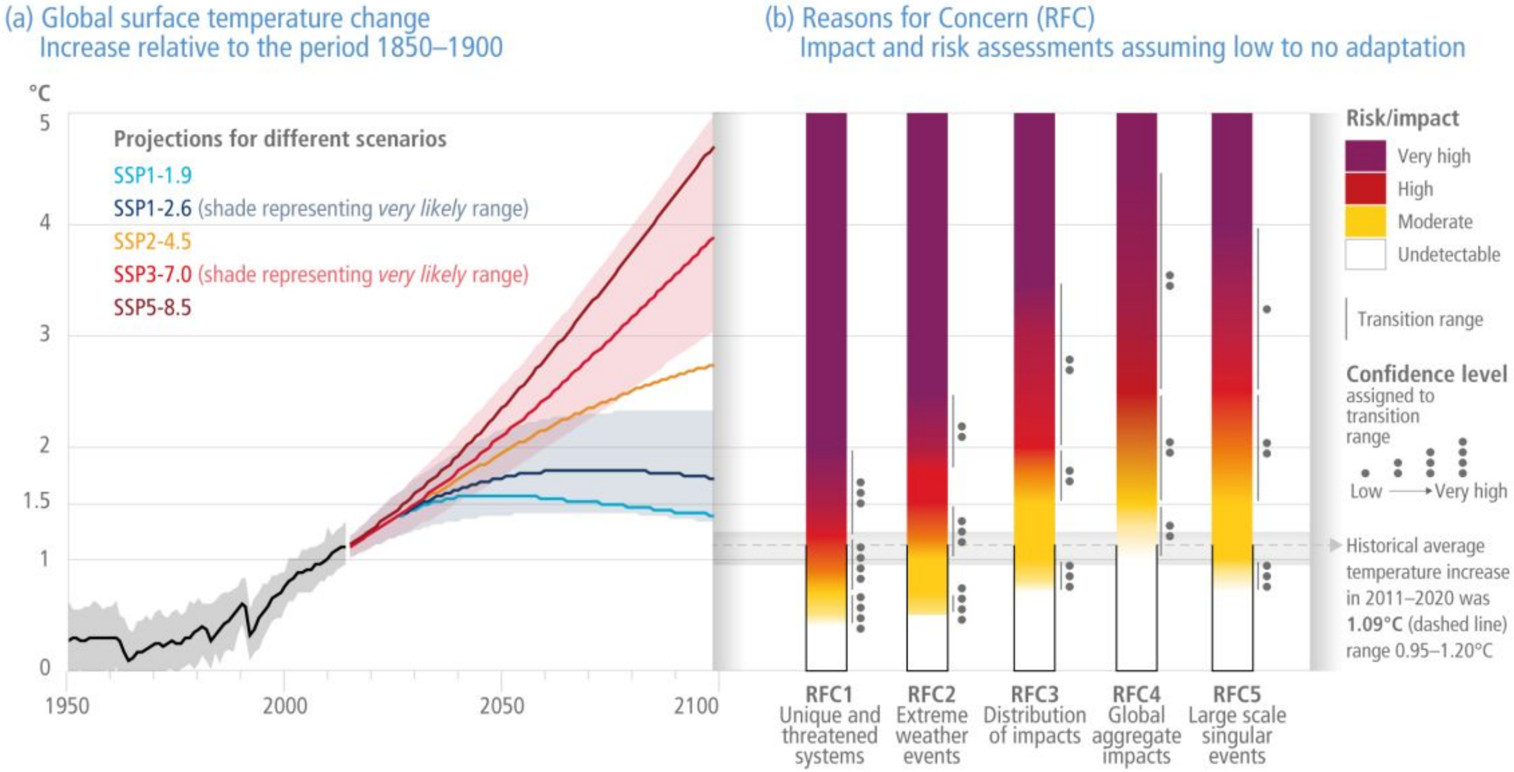
Global and regional risks for increasing levels of global warming



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Climate Change 2022

Impacts, Adaptation and Vulnerability

Summary for Policymakers

https://report.ipcc.ch/ar6wg2/pdf/IPCC_AR6_WGII_SummaryForPolicymakers.pdf

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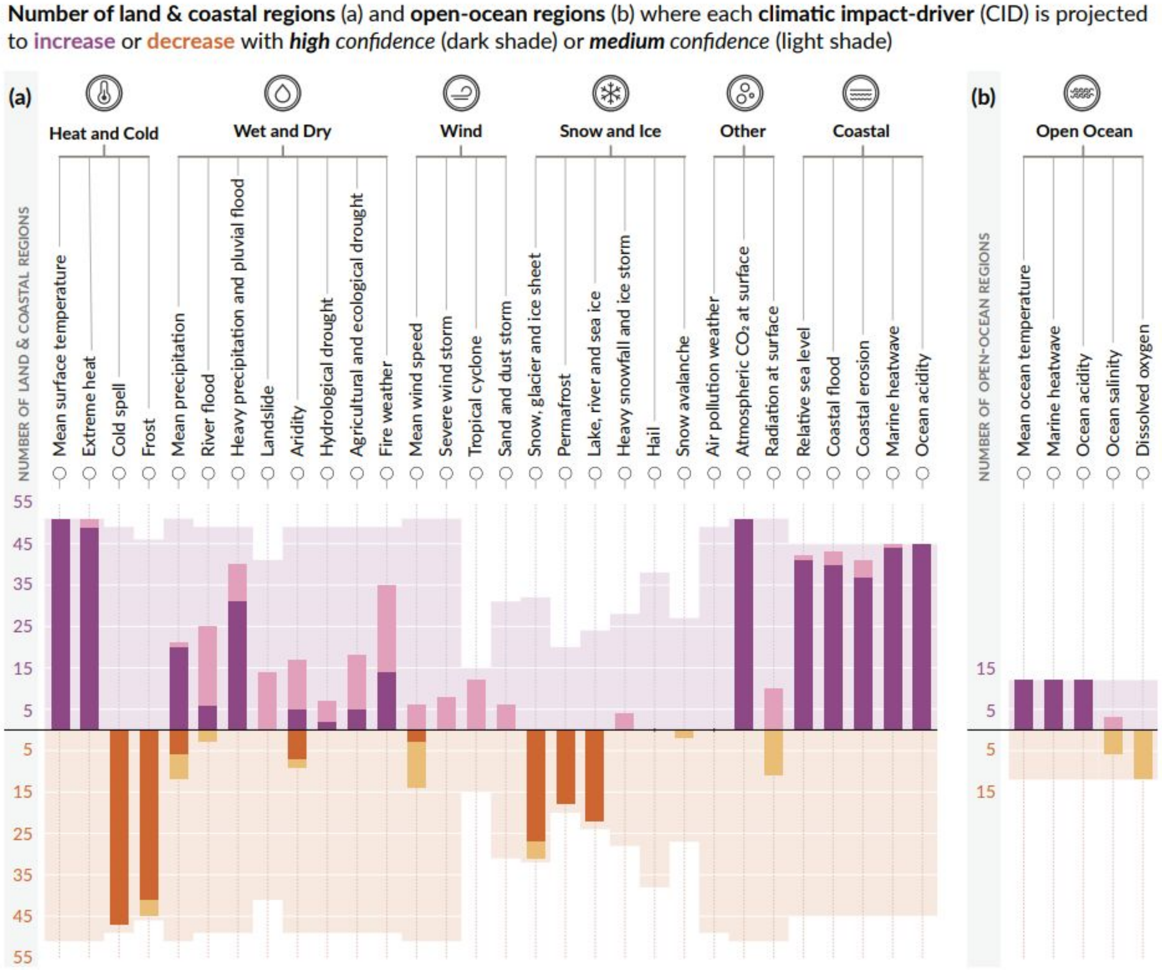
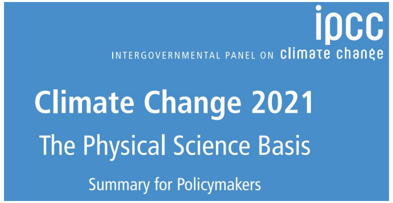
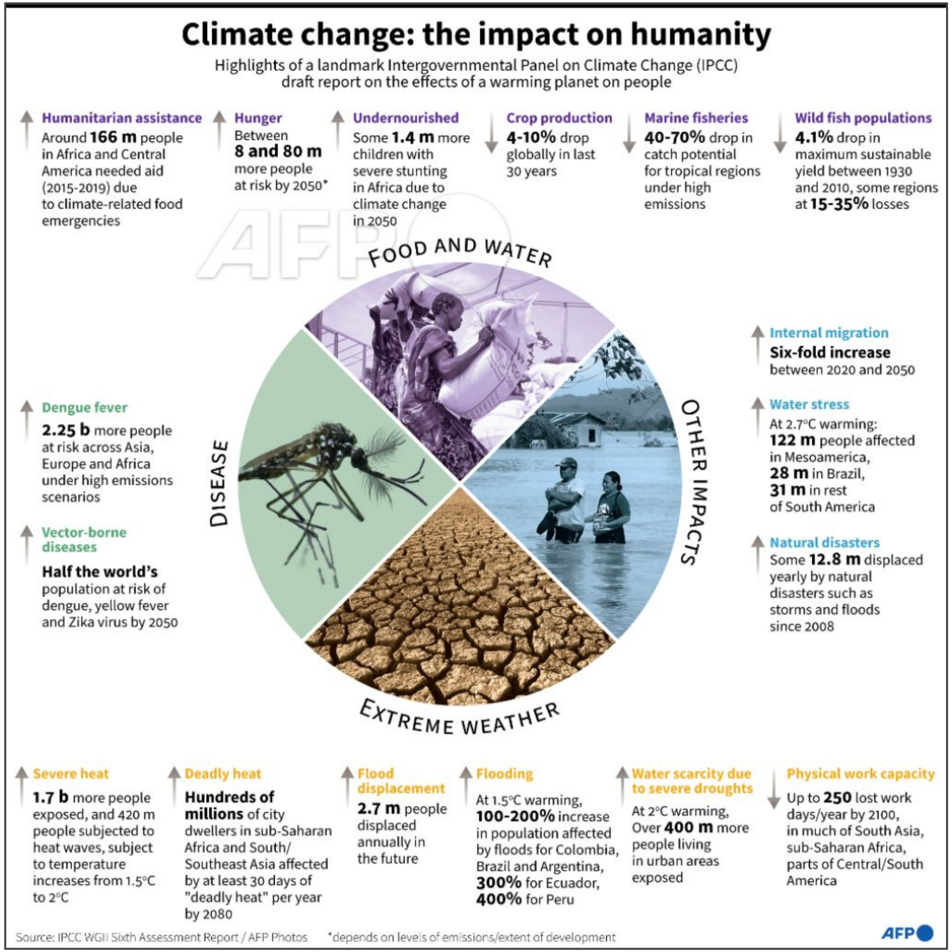
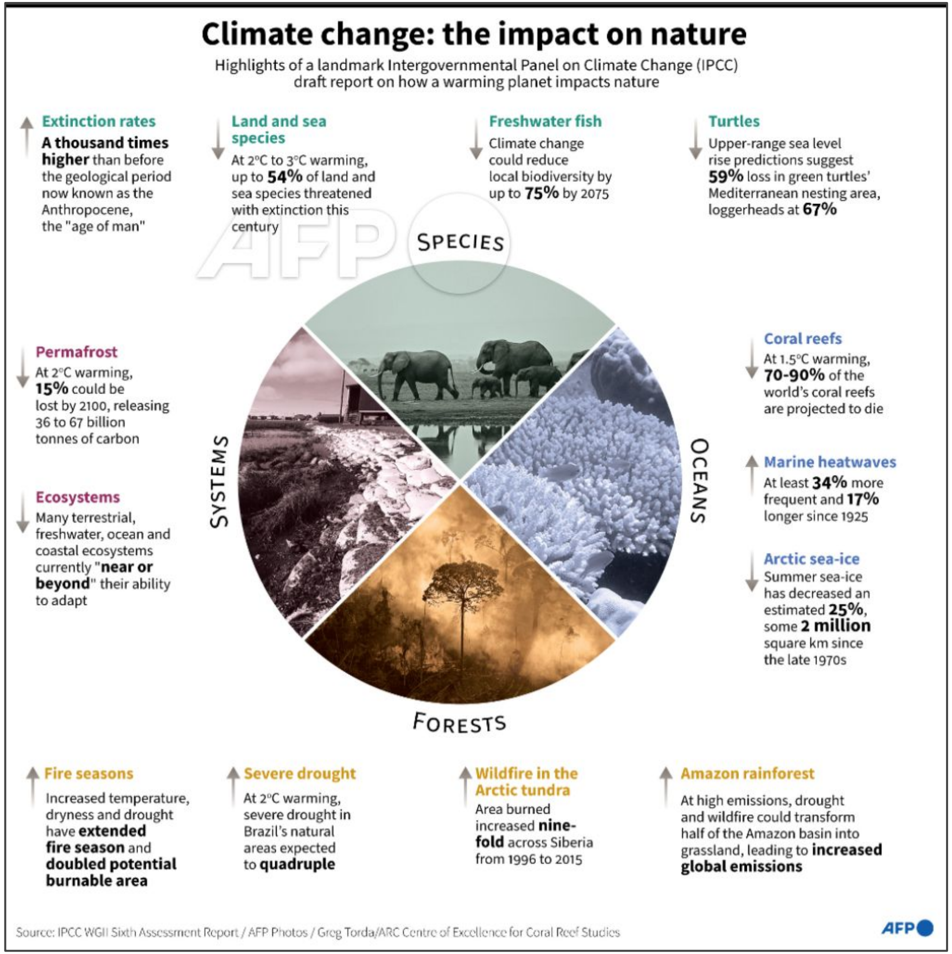




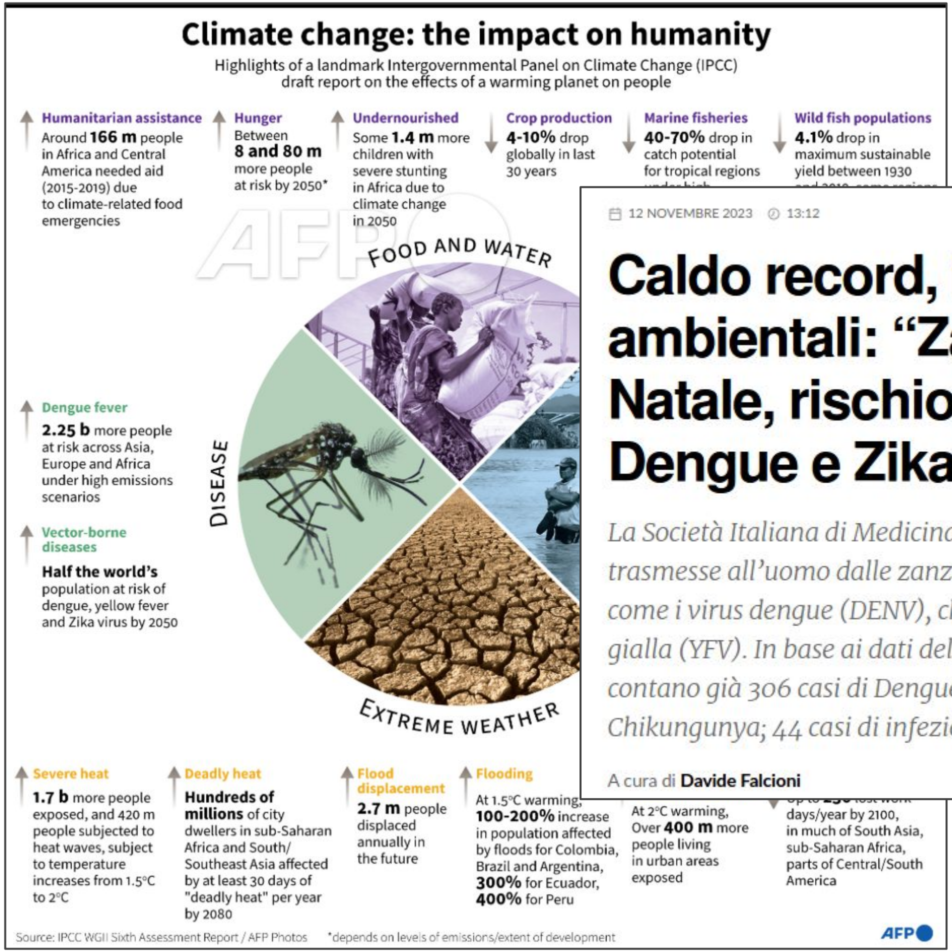
https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf

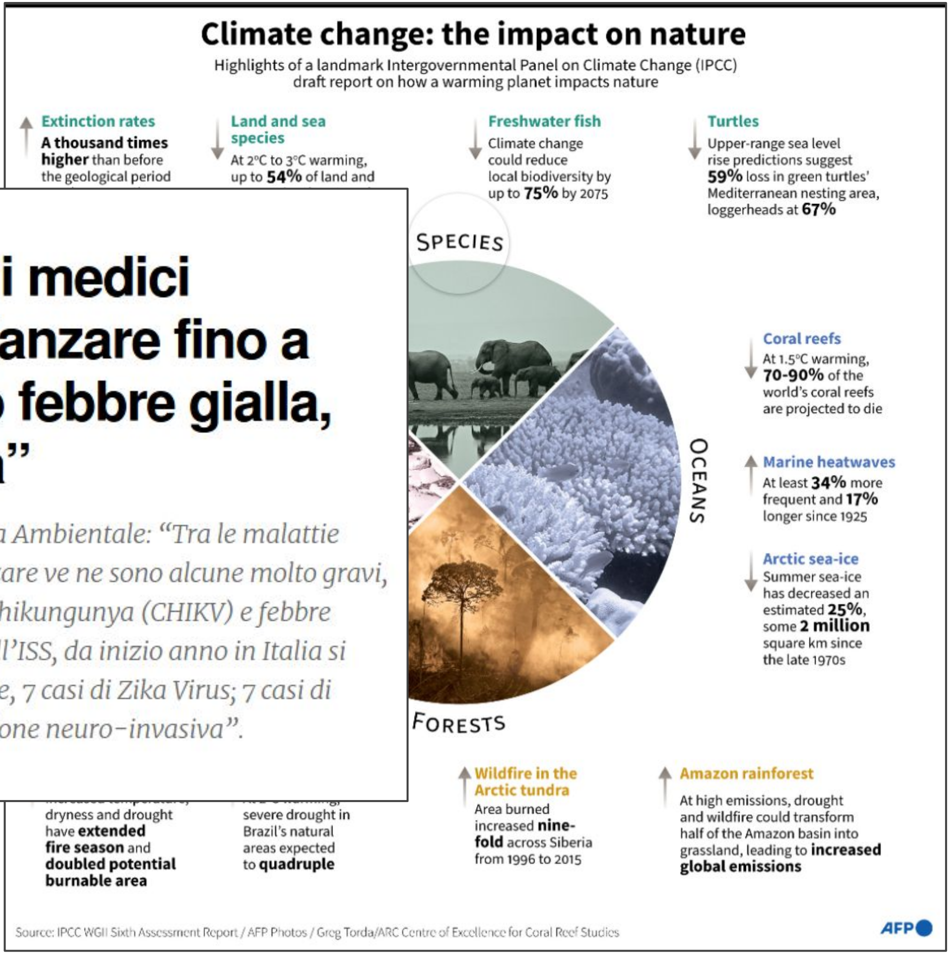




Report IPCC 2022

https://twitter.com/afp/status/1407514775882330112





12 NOVEMBRE 2023 13:12

Caldo record, i medici ambientali: "Zanzare fino a Natale, rischio febbre gialla, Dengue e Zika"

La Società Italiana di Medicina Ambientale: "Tra le malattie trasmesse all'uomo dalle zanzare ve ne sono alcune molto gravi, come i virus dengue (DENV), chikungunya (CHIKV) e febbre gialla (YFV). In base ai dati dell'ISS, da inizio anno in Italia si contano già 306 casi di Dengue, 7 casi di Zika Virus; 7 casi di Chikungunya; 44 casi di infezione neuro-invasiva".

A cura di **Davide Falcioni**

Report IPCC 2022

https://twitter.com/afp/status/1407514775882330112

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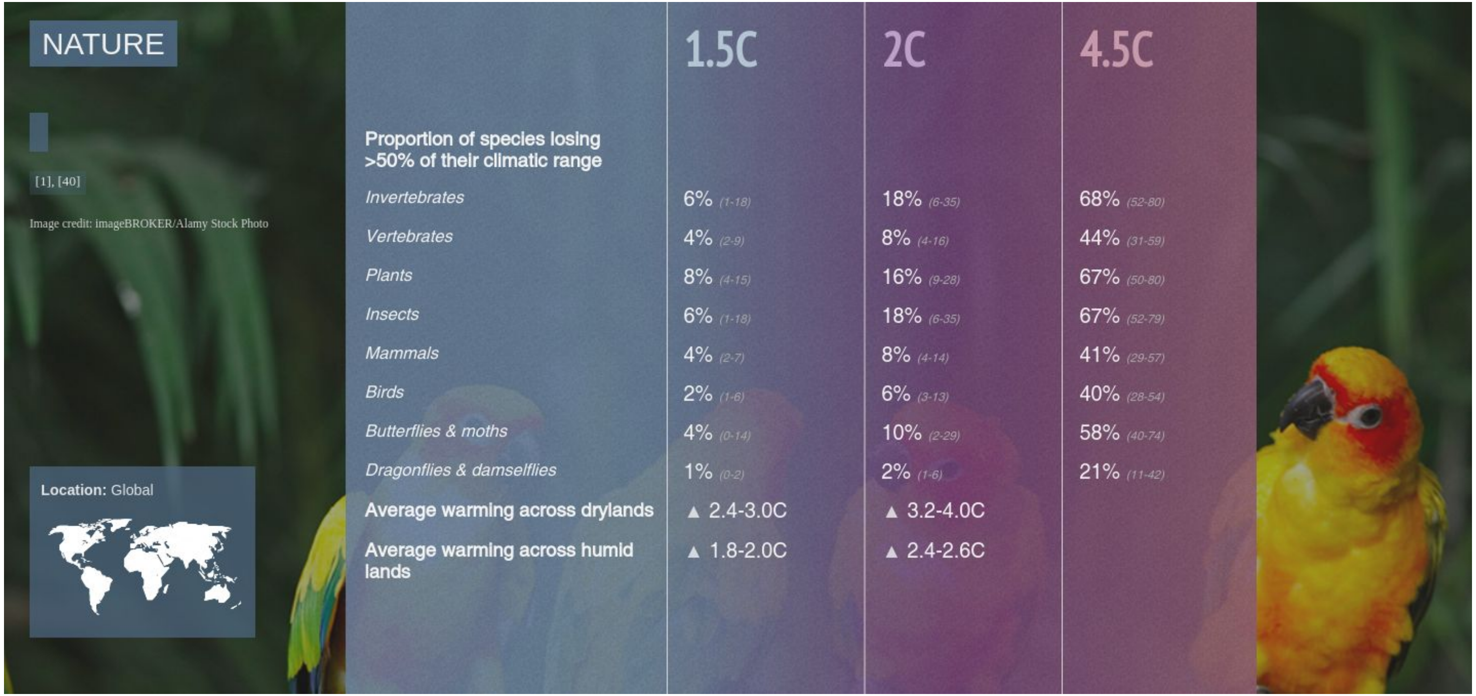
Consequences for the biosphere



Proportion of species losing >50% of their climatic range	1.5C	2C	4.5C
Invertebrates	6% (1-18)	18% (6-35)	68% (52-80)
Vertebrates	4% (2-9)	8% (4-16)	44% (31-59)
Plants	8% (4-15)	16% (9-28)	67% (50-80)
Insects	6% (1-18)	18% (6-35)	67% (52-79)
Mammals	4% (2-7)	8% (4-14)	41% (29-57)
Birds	2% (1-6)	6% (3-13)	40% (28-54)
Butterflies & moths	4% (0-14)	10% (2-29)	58% (40-74)
Dragonflies & damselflies	1% (0-2)	2% (1-6)	21% (11-42)
Average warming across drylands	▲ 2.4-3.0C	▲ 3.2-4.0C	
Average warming across humid lands	▲ 1.8-2.0C	▲ 2.4-2.6C	

https://interactive.carbonbrief.org/impacts-climate-change-one-point-five-degrees-two-degrees

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BP and Shell planning for catastrophic 5°C global warming despite publicly backing Paris climate agreement

Companies are trying to 'have their oil and drink it' by committing to 2°C in public while planning for much higher temperature rises, says shareholder campaign group, ShareAction

Ben Chapman | @b_c_chapman | Friday 27 October 2017 08:17 |
35 comments

1. Is climate changing? Is it caused by human activities? Is this debated by experts?
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3. Which are its physical causes?
4. Which human activities are more impactful?
5. What can/should we do?

Yes, within (large) uncertainties; it's *probably* going to be worse than we expect

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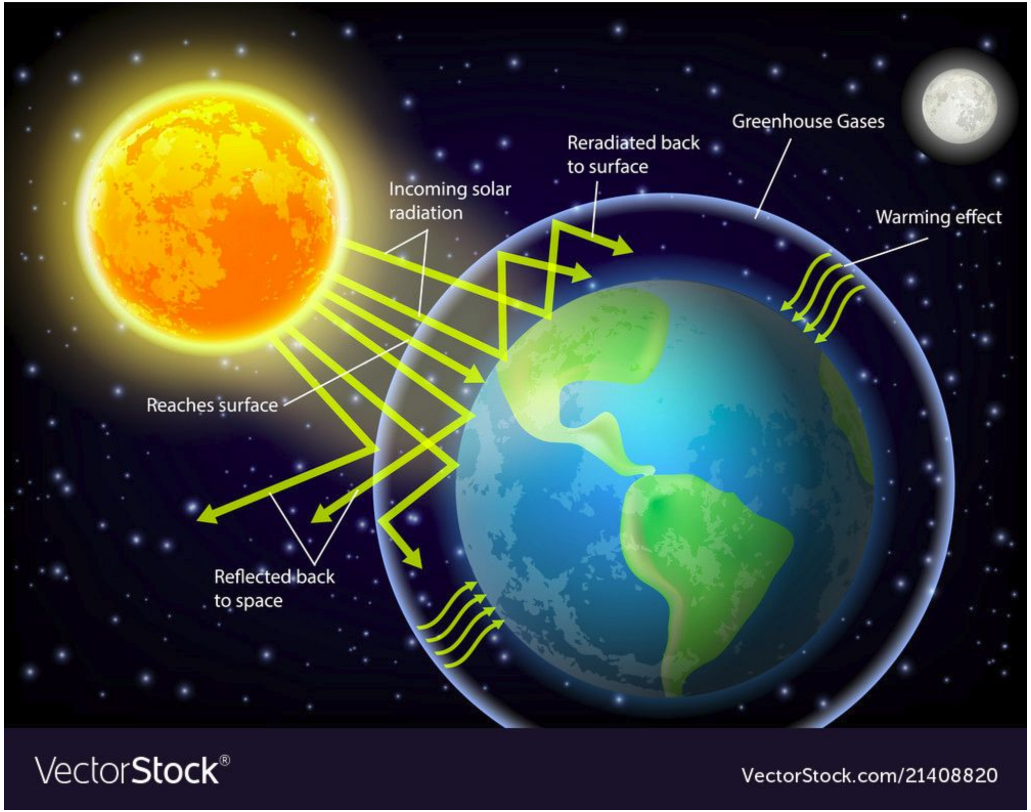
Greenhouse effect



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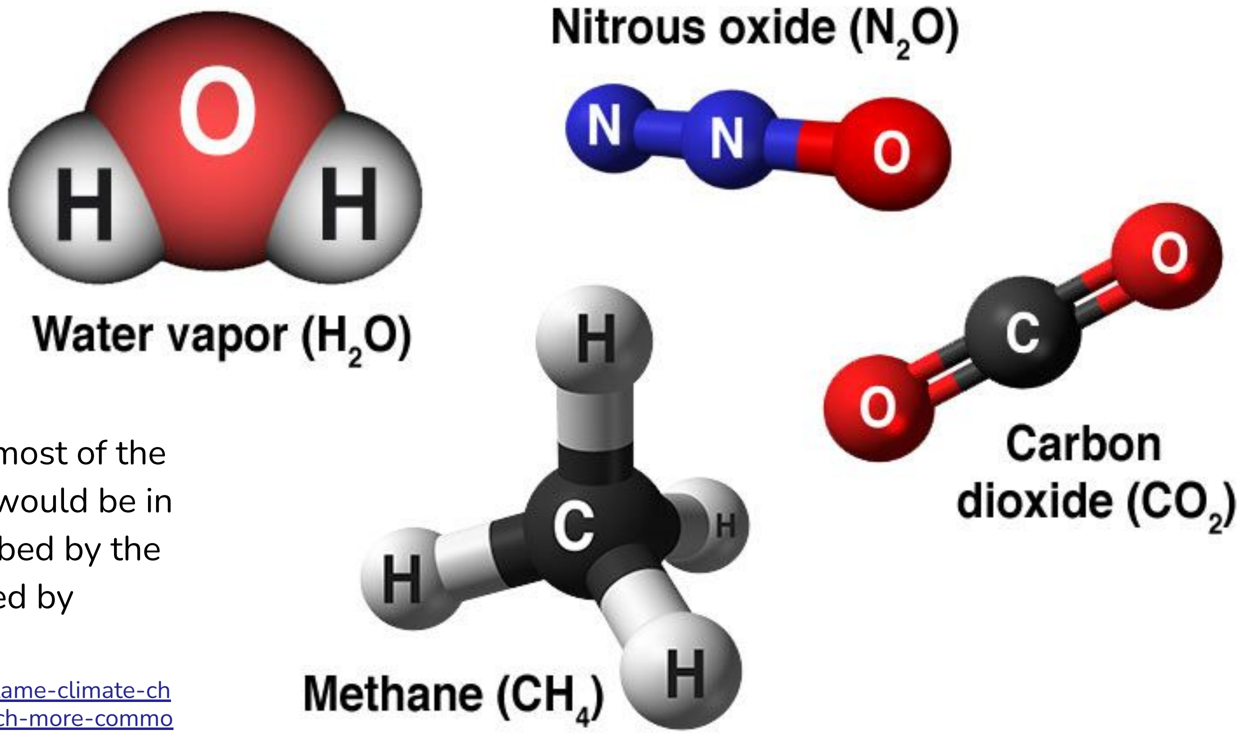
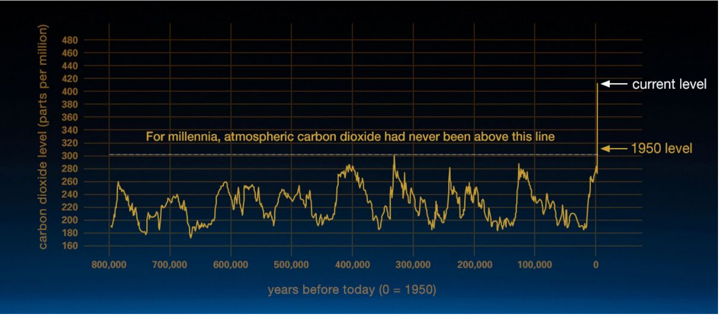
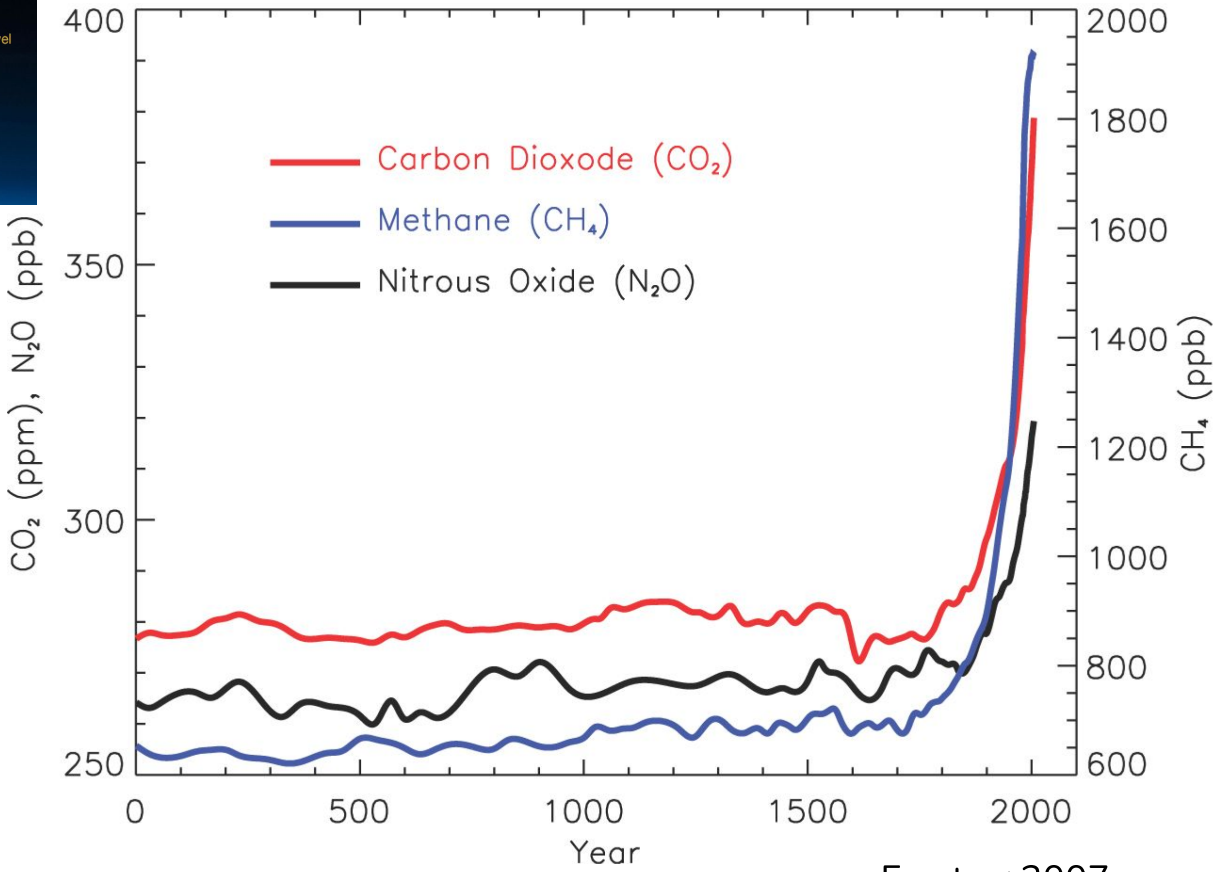
Greenhouse gases



Water vapor is responsible for most of the "good" greenhouse effect, and would be in equilibrium if it were not perturbed by the other greenhouse gases released by human activities
https://climate.mit.edu/ask-mit/why-do-we-blame-climate-change-carbon-dioxide-when-water-vapor-much-more-common-greenhouse

https://climate.nasa.gov/causes/





Forster+2007

W.r.t. pre-industrial values:

CO2: (425) +50%

CH4: (1934)+300%

N2O: (337) +30%

https://nca2009.globalchange.gov/2000-years-greenhouse-gas-concentrations/index.html

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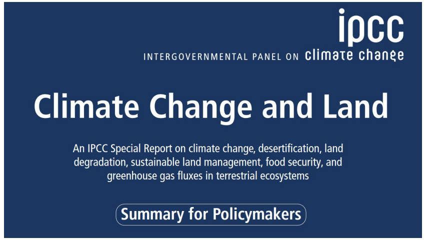
Table SPM1. Net anthropogenic emissions due to Agriculture, Forestry, and other Land Use (AFOLU) and non-AFOLU (Panel 1) and global food systems (average for 2007-2016)[1] (Panel 2). Positive value represents emissions; negative value represents removals.

		Direct Anthropogenic							
		Net anthropogenic emissions due to Agriculture, Forestry, and Other Land Use (AFOLU)			Non-AFOLU anthropogenic GHG emissions[6]	Total net anthropogenic emissions (AFOLU + non-AFOLU) by gas	AFOLU as a % of total net anthropogenic emissions, by gas	Natural response of land to human-induced environmental change[7]	Net land – atmosphere flux from all lands
Panel 1: Contribution of AFOLU									
		FOLU	Agriculture	Total					
		A	B	C = B + A	D	E = C + D	F = (C/E)*100	G	A + G
CO_2[2]	Gt CO_2 y^{-1}	5.2 ± 2.6	--[11]	5.2 ± 2.6	33.9 ± 1.8	**39.1 ± 3.2**	~13%	-11.2 ± 2.6	-6.0 ± 2.0
CH_4[3,8]	Mt CH_4 y^{-1}	19 ± 6	142 ± 43	162 ± 48.6	201 ± 100	**363 ± 111**			
	Gt CO_2e y^{-1}	0.5 ± 0.2	4.0 ± 1.2	4.5 ± 1.4	5.6 ± 2.8	**10.1 ± 3.1**	~44%		
N_2O[3,8]	Mt N_2O y^{-1}	0.3 ± 0.1	8 ±2	8.3 ± 2.5	2.0 ± 1.0	**10.4 ± 2.7**			
	Gt CO_2e y^{-1}	0.09 ± 0.03	2.2 ± 0.7	2.3 ± 0.7	0.5 ± 0.3	**2.8 ± 0.7**	~82%		
Total (GHG)	**Gt CO_2e y^{-1}**	**5.8 ± 2.6**	**6.2 ± 1.4**	**12.0 ± 3.0**	**40.0 ± 3.4**	**52.0 ± 4.5**	**~23%**		



CO_2 → 39.1 Gt/yr
CH_4 → 0.363 Gt/yr

https://www.ipcc.ch/site/assets/uploads/2019/08/Fullreport-1.pdf

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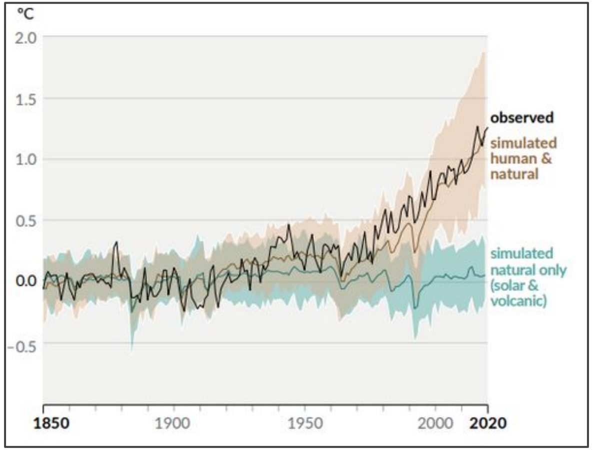
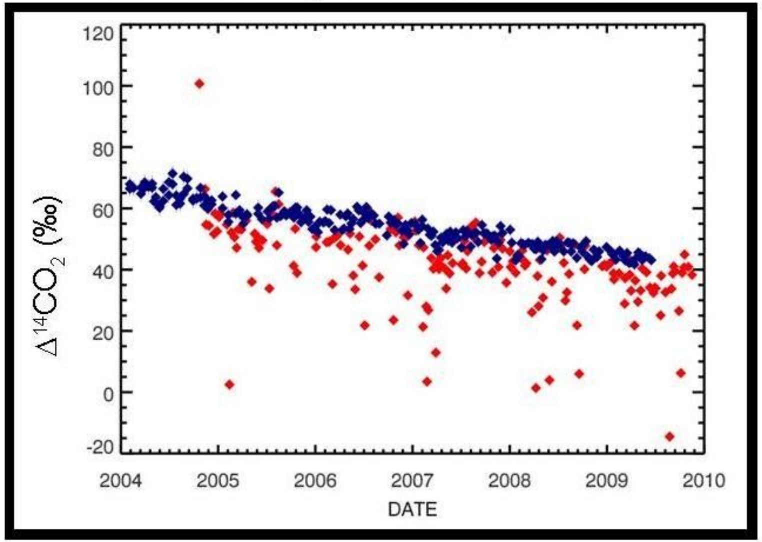
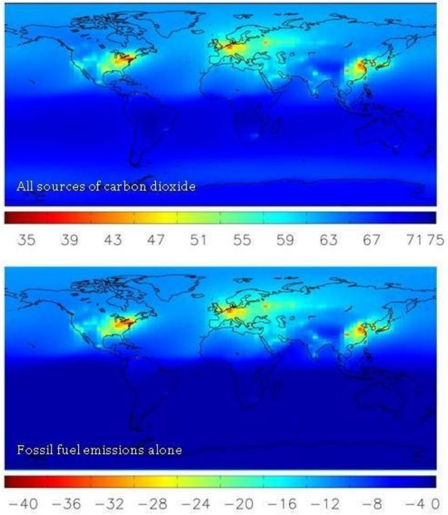
Carbon dioxide

How do we know it's anthropogenic?



Measured $\Delta^{14}CO_2$ in East Asia and Colorado





https://www.esrl.noaa.gov/gmd/education/isotopes/c14tellsus.html

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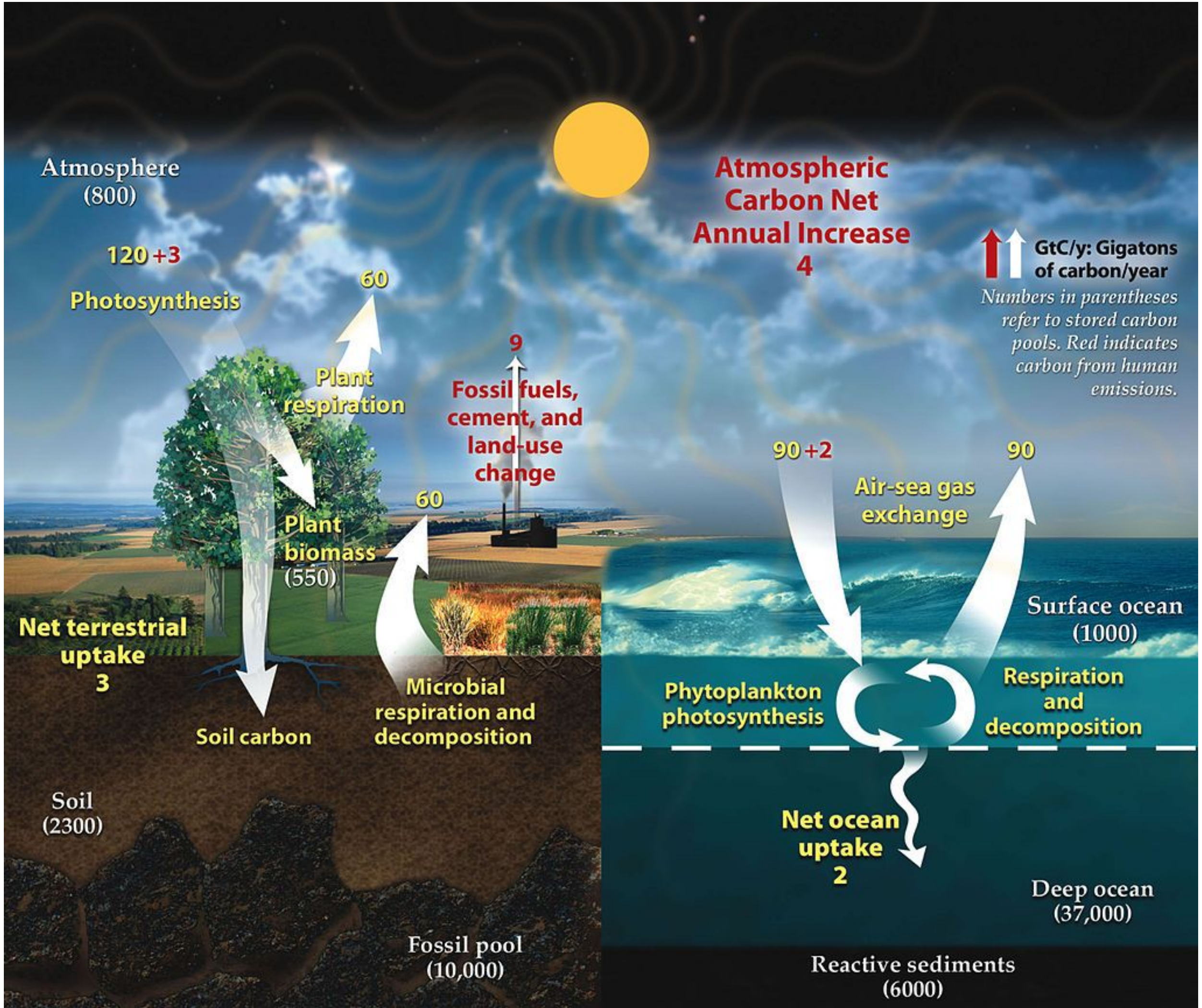
Carbon cycle



https://earthobservatory.nasa.gov/features/CarbonCycle

GLOBAL CARBON project

Fate of anthropogenic CO_2 emissions (2013–2022)

Sources = Sinks

35.3 $GtCO_2$/yr
88%

12%
4.7 $GtCO_2$/yr

Trees and other plants absorb carbon dioxide from the atmosphere as they grow. This is converted into carbon and stored in the plant's branches, leaves, trunks, roots and in the soil.

When forests are cleared or burnt, stored carbon is released into the atmosphere, mainly as carbon dioxide.

18.9 $GtCO_2$/yr
47%

31%
12.3 $GtCO_2$/yr

26%
10.4 $GtCO_2$/yr

Budget Imbalance:
(the difference between estimated sources & sinks)

4%
-1.6 $GtCO_2$/yr

Source: Friedlingstein et al 2023; Global Carbon Project 2023

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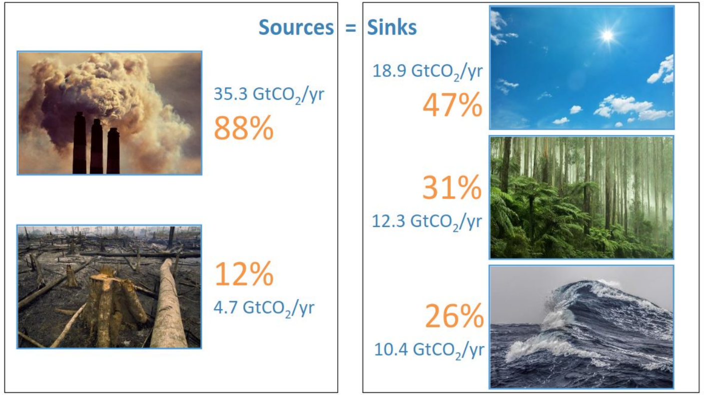
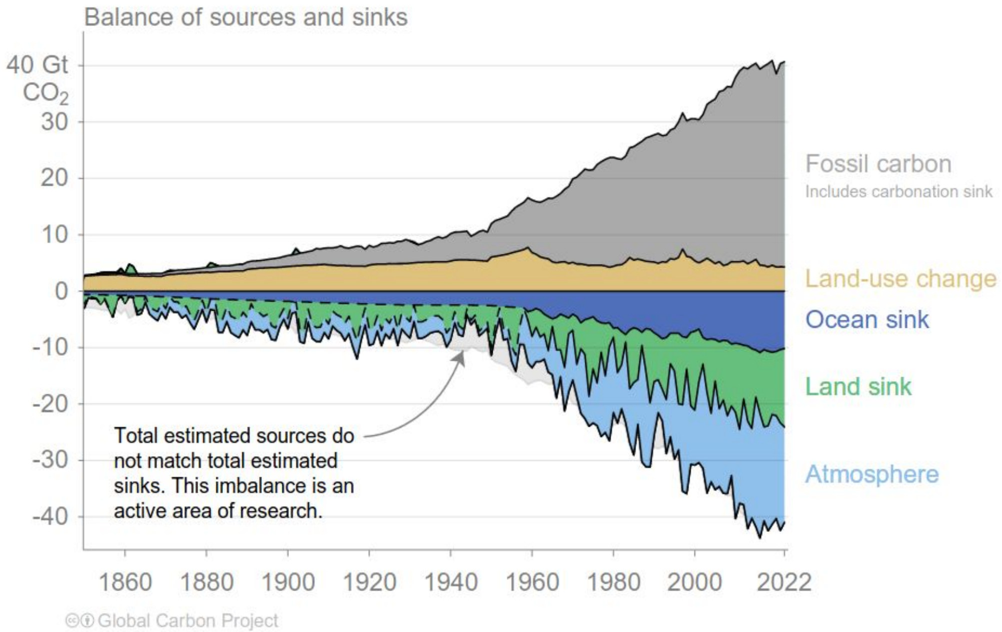
Carbon emissions are partitioned among the atmosphere and carbon sinks on land and in the ocean
The “imbalance” between total emissions and total sinks is an active area of research





https://www.globalcarbonproject.org/index.htm

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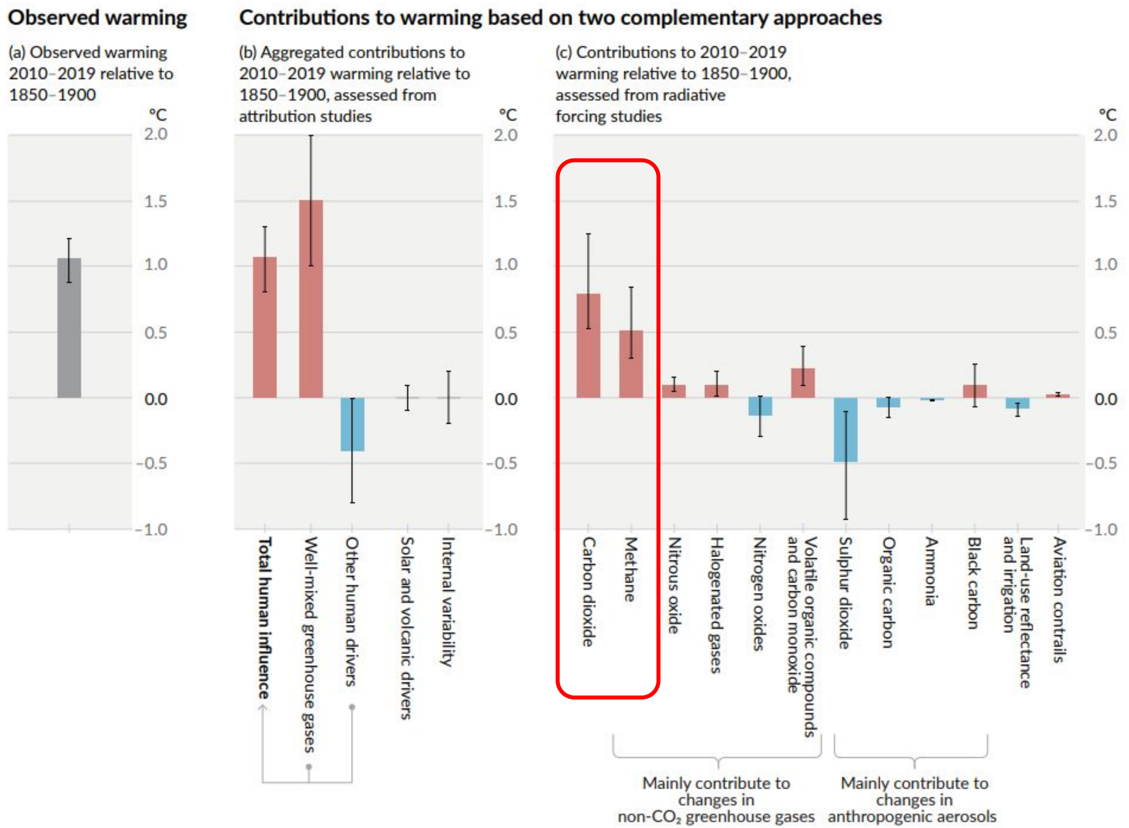
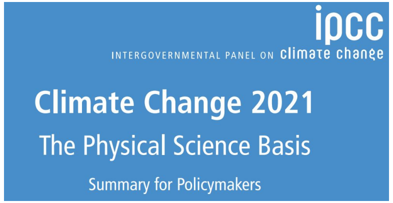
Methane

CO_2 → 39.1 Gt/yr
CH_4 → 0.363 Gt/yr

Observed warming is driven by emissions from human activities, with greenhouse gas warming partly masked by aerosol cooling





https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf

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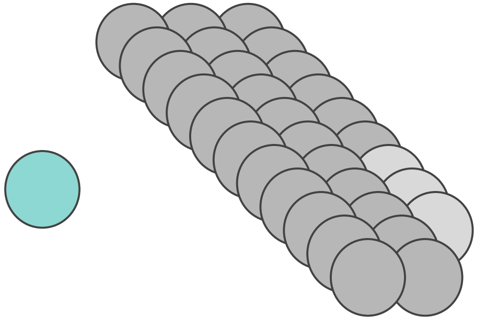
Global Warming Potential

Substance	AR1 (1990)	AR2 (1995)	AR3 (2001)	AR4 (2007)	AR5 (2013)
Carbon dioxide, fossil (CO_2)	1	1	1	1	1
Methane, fossil (CH_4)	21	21	23	25	28
Methane, biogenic (CH_4)	18.25	18.25	20.25	22.25	25.25
Dinitrogen monoxide (N_2O)	290	310	296	298	265
HCFC-141b	440	-	700	725	782
HFC-134a	1200	1300	1300	1430	1300
HCFC-22	1500	-	1700	1810	1760
HCFC-142b	1600	-	2400	2310	1980
CFC-11	3500	-	4600	4750	4660
CFC-12	7300	-	10600	10900	10200
Sulfur hexafluoride	-	23900	22200	22800	23500



1 ton CH4 ≈25-28 ton CO2
IPCC 2019 report

https://www.ipcc.ch/assessment-report/ar5/

CH4 → 28 x 0.363 = 10.16 GtCO2eq/yr

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Table 1.1 | Implications of the choice of Global Warming Potential (GWP) for mitigation strategy. Table shows the main geophysical properties of the major Kyoto gases and the implications of the choice of values for GWPs with different time horizons (20, 100, or 500 years) on the share of weighted total emissions for 2010; other IPCC chapters report detail on alternative indexes such as Global Temperature change Potential (GTP) (Chapter 3; WGI Chapter 8). At present, the 100-year GWPs are used most widely, and we show those values as reported in the IPCC Second Assessment Report (SAR) in 1995 and subsequently used in the Kyoto Protocol. Note that CO_2 is removed by multiple processes and thus has no single lifetime (see WGI Box 6.1). We show CF_4 as one example of the class of perfluorocarbons (PFCs) and HFC-134a and HFC-23 as examples of hydrofluorocarbons (HFCs). All other industrial fluorinated gases listed in the Kyoto Protocol ('F-gases') are summed. We do not show warming agents that are not included in the Kyoto Protocol, such as black carbon. Emissions reported in JRC/PBL (2013) using GWPs reported in IPCC's Second, Fourth and Fifth Assessment Reports (IPCC, 1995, 2007c, 2013a). The AR4 was used for GWP-500 data; interpretation of long time horizon GWPs is particularly difficult due to uncertainties in carbon uptake and climate response—differences that are apparent in how different models respond to different pulses and scenarios for CO_2 and the many nonlinearities in the climate system (see WGI, Supplemental Material 8.SM.11.4 and Joos et al., 2013) and thus IPCC no longer reports 500 year GWPs. Due to changes in the GWP values from AR4 to AR5 the 500-year shares are not precisely comparable with the other GWPs reported here. Geophysical properties of the gases drawn from WGI, Appendix 8.A, Table 8.A.1—final draft data).

Kyoto gases	Geophysical properties		GWP-weighted share of global GHG emissions in 2010			
	Atmospheric lifetime (year)	Instantaneous forcing ($W/m^2/ppb$)	SAR (Kyoto)	WGI (20 and 100 year from AR5 & 500 year from AR4)		
			100 years	20 years	100 years	500 years
CO_2	various	1.37×10^{-5}	76 %	52 %	73 %	88 %
CH_4	12.4	3.63×10^{-4}	16 %	42 %	20 %	7 %
N_2O	121	3.00×10^{-3}	6.2 %	3.6 %	5.0 %	3.5 %
F-gases:			2.0 %	2.3 %	2.2 %	1.8 %
HFC-134a	13.4	0.16	0.5 %	0.9 %	0.4 %	0.2 %
HFC-23	222	0.18	0.4 %	0.3 %	0.4 %	0.5 %
CF_4	50,000	0.09	0.1 %	0.1 %	0.1 %	0.2 %
SF_6	3,200	0.57	0.3 %	0.2 %	0.3 %	0.5 %
NF_3 *	500	0.20	not applicable	0.0 %	0.0 %	0.0 %
Other F-gases **	various	various	0.7 %	0.9 %	0.8 %	0.4 %

* NF_3 was added for the second commitment period of the Kyoto period, NF_3 is included here but contributes much less than 0.1 %.

** Other HFCs, PFCs and SF_6 included in the Kyoto Protocol's first commitment period. For more details see the Glossary (Annex I).

Climate Change 2014
Mitigation of Climate Change

INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_full.pdf

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GLEAM model (2019)

These three primary GHGs vary greatly in their ability to trap heat and in their persistence in the atmosphere, giving different GWPs at different time horizons. Table 2 shows that methane is relatively short-lived compared to CO_2 and N_2O, which persist in the atmosphere for much longer. This has a profound impact on the estimation of GWP, whereby the contribution of methane to GWP at 20 years after an emission (GWP_{20}) is considerably greater than its contribution after 100 years (GWP_{100}) (Table 2 and Figure 8). For emission estimates derived from GLEAM 2 in this document, CO_2 eq. is calculated as GWP_{100}. There is ongoing scientific debate about the way that methane should be accounted for relative to carbon dioxide (e.g. Allen *et al*. 2018), but the quantity produced and high radiative forcing of the gas means that short-term impacts are considerable, and its shorter atmospheric duration means that actions to reduce methane can have a relatively quick impact on global warming, making methane a current priority for action.

TABLE 2. Atmospheric duration and global warming potential of the priority greenhouse gases

Gas	Atmospheric duration (years)	After 20 years		After 100 years	
		GWP_{20}**	Livestock emissions ($Gt CO_2$ eq. per year)	GWP_{100}	Livestock emissions ($Gt CO_2$ eq. per year)
CO_2	*	1	2.1	1	2.1
CH_4	12.4	86	10.1	34	4.0
N_2O	121	268	1.7	298	1.9
Total livestock emissions	–	–	13.9	–	8.0

http://www.fao.org/3/ca7089en/ca7089en.pdf

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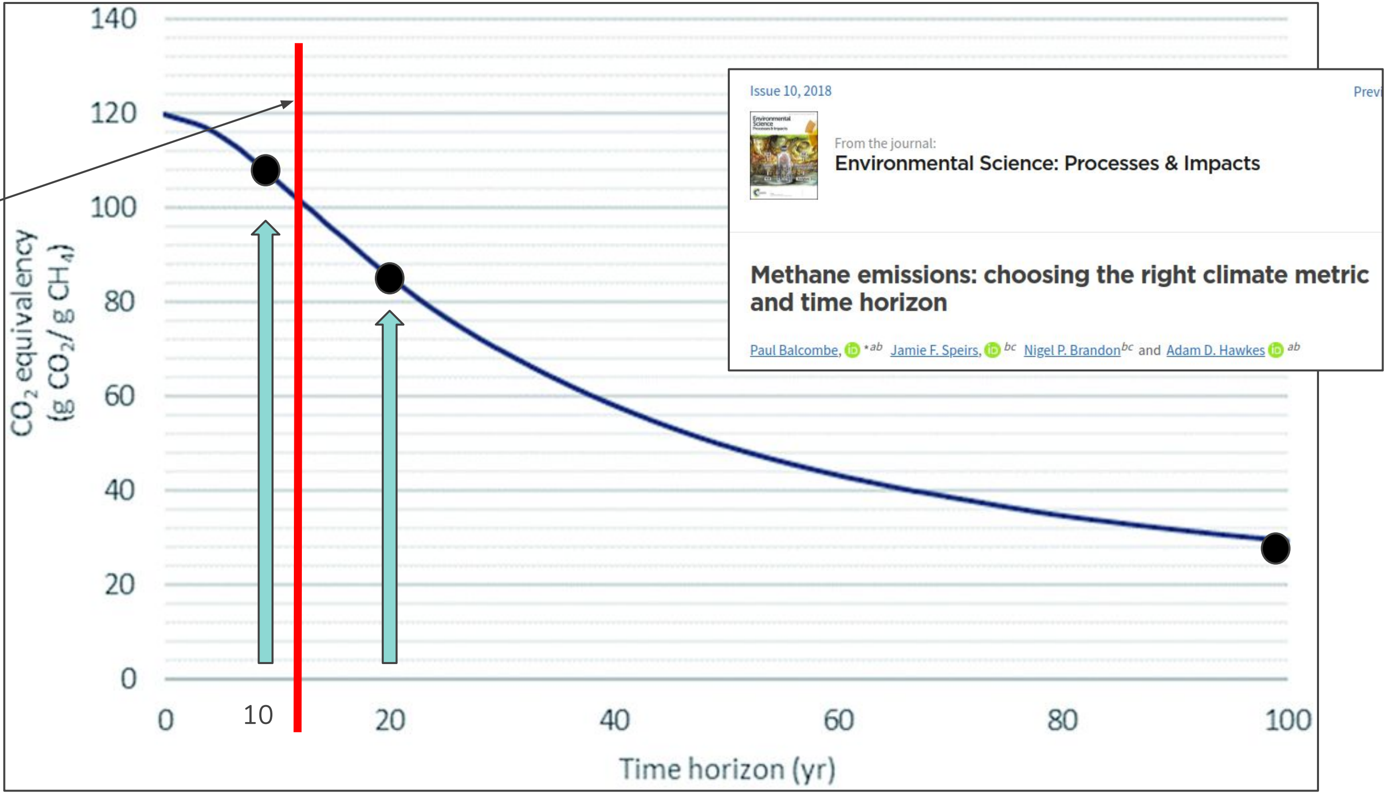
Methane GWP as a function of time horizon

Methane average lifetime in atmosphere: ~12 years



https://pubs.rsc.org/en/content/articlelanding/2018/em/c8em00414e#!divAbstract

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ipcc
INTERGOVERNMENTAL PANEL ON climate change

Climate Change and Land

An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems

Summary for Policymakers

Table SPM1. Net anthropogenic emissions due to Agriculture, Forestry, and other Land Use (AFOLU) and non-AFOLU (Panel 1) and global food systems (average for 2007-2016)[1] (Panel 2). Positive value represents emissions; negative value represents removals.

		Direct Anthropogenic						
		Net anthropogenic emissions due to Agriculture, Forestry, and Other Land Use (AFOLU)			Non-AFOLU anthropogenic GHG emissions[6]	Total net anthropogenic emissions (AFOLU + non-AFOLU) by gas	AFOLU as a % of total net anthropogenic emissions, by gas	Natural response of land to human-induced environmental change[7]
Panel 1: Contribution of AFOLU								
		FOLU	Agriculture	Total				
		A	B	C = B + A	D	**E = C + D**	F = (C/E)*100	G
CO_2[2]	Gt CO_2 y^{-1}	5.2 ± 2.6	--[11]	5.2 ± 2.6	33.9 ± 1.8	**39.1 ± 3.2**	~13%	-11.2 ± 2.6
CH_4[3,9]	Mt CH_4 y^{-1}	19 ± 6	142 ± 43	162 ± 48.6	201 ± 100	**363 ± 111**		
	Gt CO_2e y^{-1}	0.5 ± 0.2	4.0 ± 1.2	4.5 ± 1.4	5.6 ± 2.8	**10.1 ± 3.1**	~44%	
N_2O[3,8]	Mt N_2O y^{-1}	0.3 ± 0.1	8 ±2	8.3 ± 2.5	2.0 ± 1.0	**10.4 ± 2.7**		
	Gt CO_2e y^{-1}	0.09 ± 0.03	2.2 ± 0.7	2.3 ± 0.7	0.5 ± 0.3	**2.8 ± 0.7**	~82%	
Total (GHG)	**Gt CO_2e y^{-1}**	**5.8 ± 2.6**	**6.2 ± 1.4**	**12.0 ± 3.0**	**40.0 ± 3.4**	**52.0 ± 4.5**	**~23%**	

CO2 → 39.1 Gt/yr
CH4 → 0.363 Gt/yr

CO2 → 0.5 x 39.1 = 19.55 Gt/yr
CH4 → ~~28~~ 110 x 0.363 = 39.93 GtCO2eq/yr

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1. Is climate changing? Is it caused by human activities? Is this debated by experts?
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3. Which are its physical causes?
4. Which human activities are more impactful?
5. What can/should we do?

Anthropogenic greenhouse gases. CO2 on long time scales; currently, CH4 causes most of warming rate

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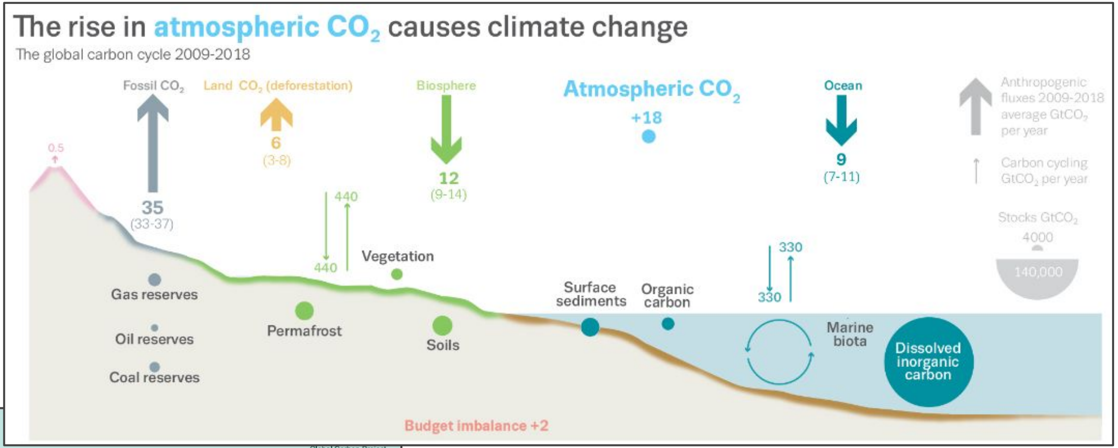
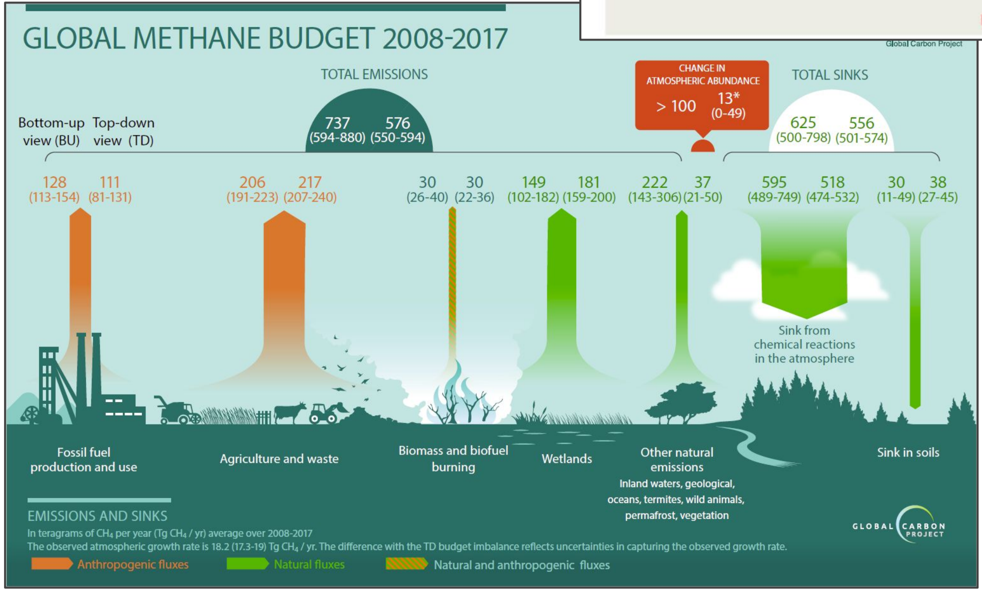
Anthropogenic sources of greenhouse gases

https://www.globalcarbonproject.org/





Anthropogenic emissions

CO2 41 Gt/yr
Fossil fuels 35 Gt/yr = 85%
Land use 6 Gt/yr = 15%

CH4 358 Mt/yr (62% of total)
[+ Natural 218 Mt/yr (38% of total)]
Fossil fuels 128 Mt/yr = 35%
Animal farming 111 Mt/yr = 31%
Waste management 65+5 Mt/yr = 20%
Rice cultivation 30 Mt/yr = 7%
Biomass/biofuel 30 Mt/yr = 7%

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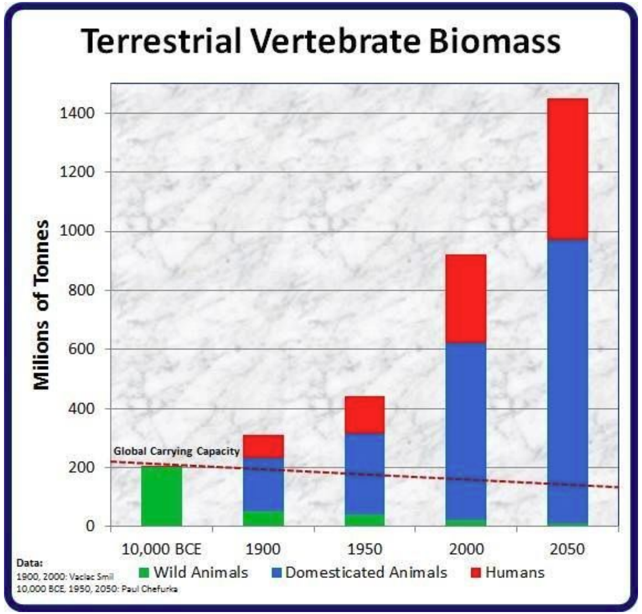
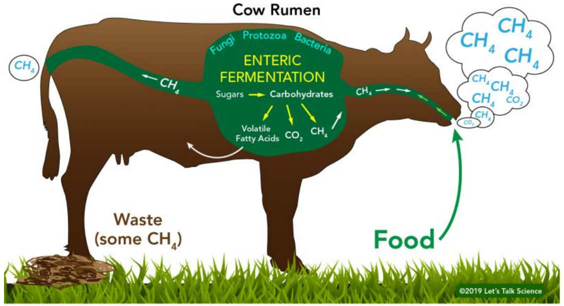
APPROXIMATE NUMBER OF LIVING SPECIMENS
(quick Wiki search)
hainan gibbon 20
mediterranean monk seal 700
tiger 4000
black rhino 5000
red panda 10 thousand
blue whale 15 thousand
Leo 20 thousand
polar bear 30 thousand
leopard 75 thousand
long-eared owl 120 thousand
gorillas 150 thousand
golden eagle 170 thousand
chimpanzees 250 thousand
american bison 500 thousand
emperor penguin 600 thousand
african buffalo, american black bear 900 thousand
eagle owl 1 million
peregrine falcon 1.2 million
kestrel 5 million
mule 10 million
common cuckoo 50 million
horse 60 million
swift 100 million
pheasant 150 million
dove 475 million



domestic cat 600 million
domestic goat 850 million
dog 900 million
ox (cow), pig (sow), sheep 1 billion
rat 7 billion
man 8 billion
rooster (hens) 24 billion



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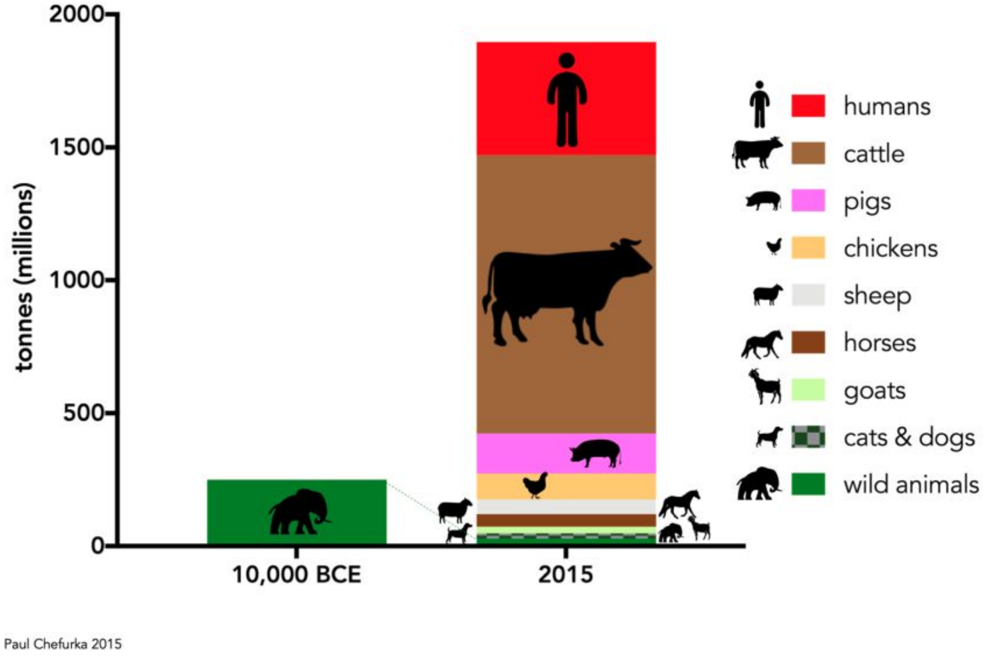
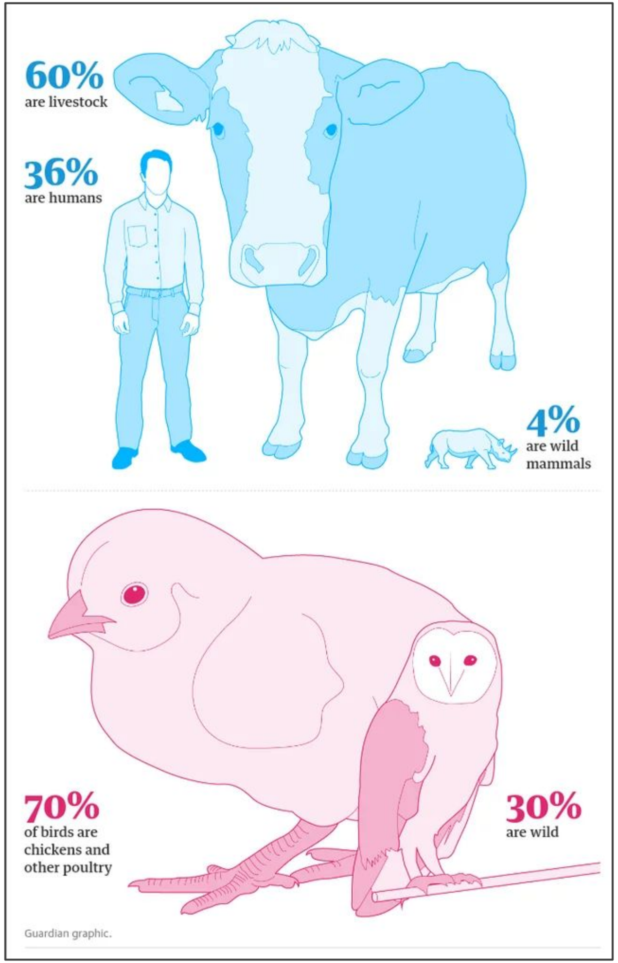
Biomass of earth mammals & birds





https://www.pnas.org/content/115/25/6506

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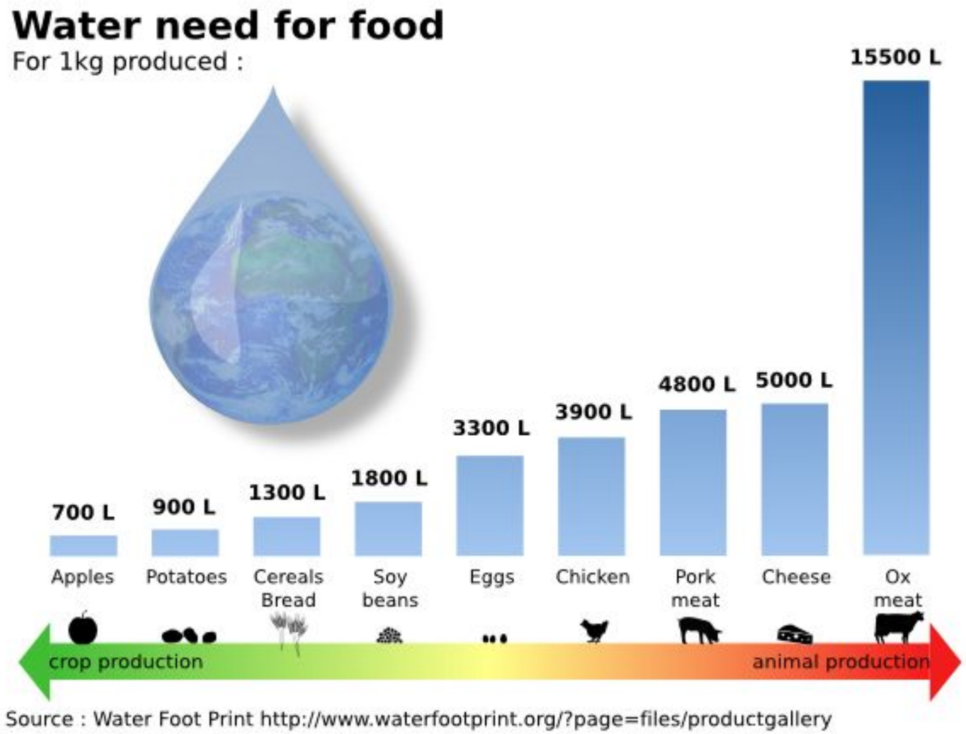
It's not just direct CH4 emissions



"Agriculture accounts for 92% of the freshwater footprint of humanity; almost one third relates to animal products"
https://www.sciencedirect.com/science/article/pii/S2212371713000024

https://ec.europa.eu/jrc/en/news/water-footprint-eu-different-diets-9674

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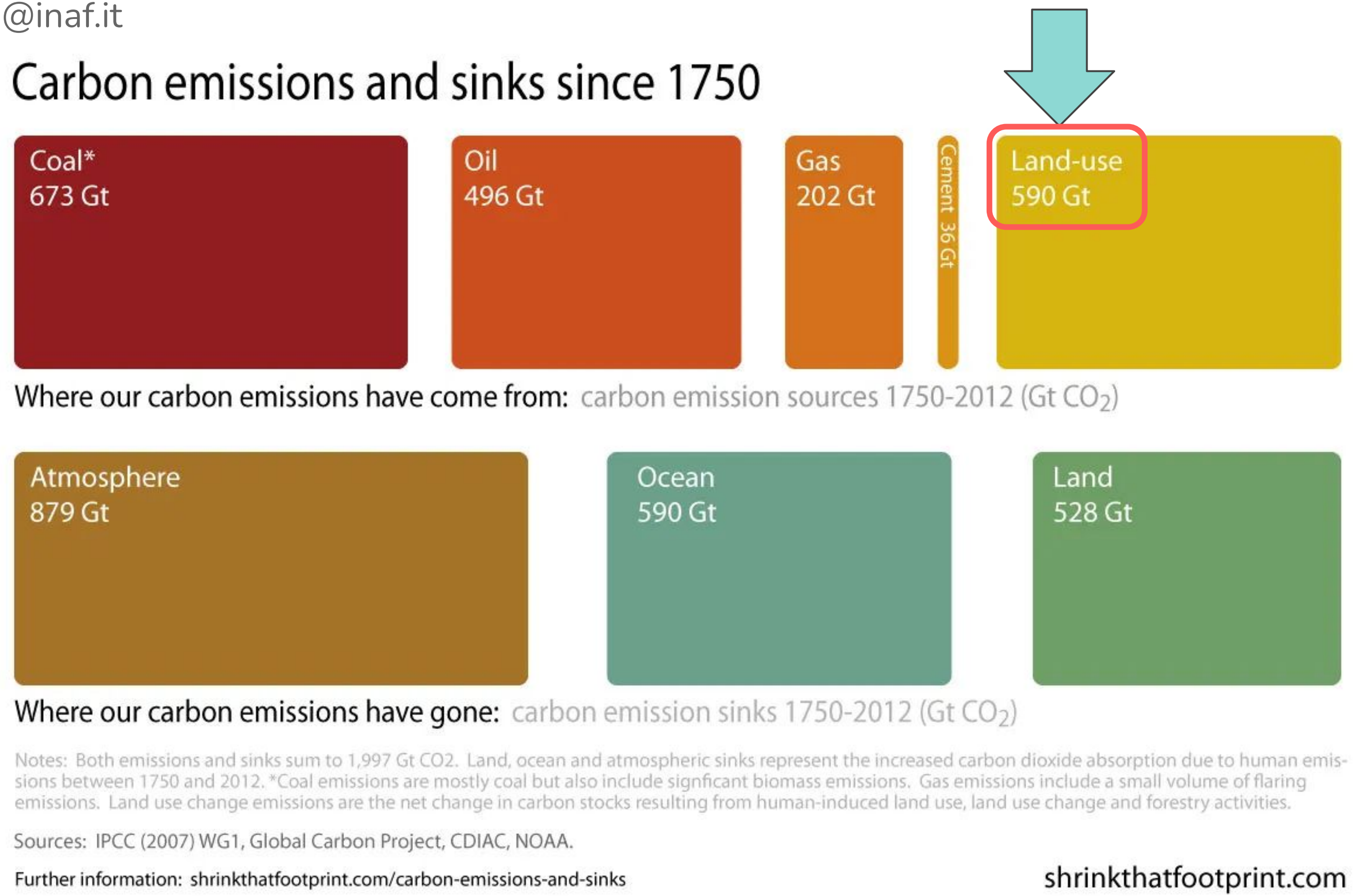
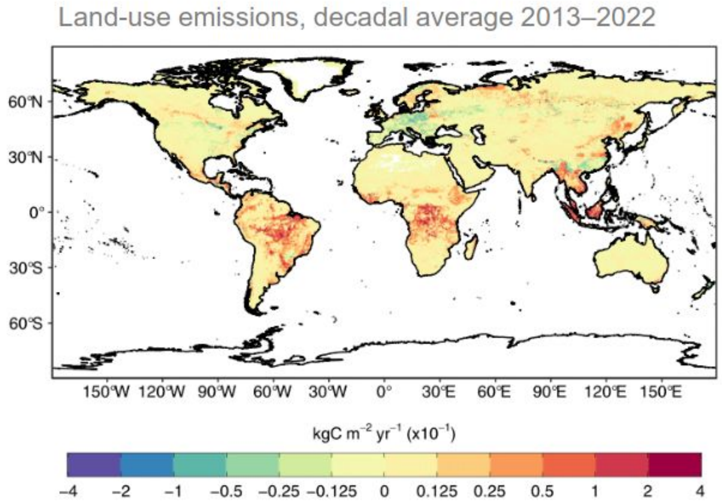


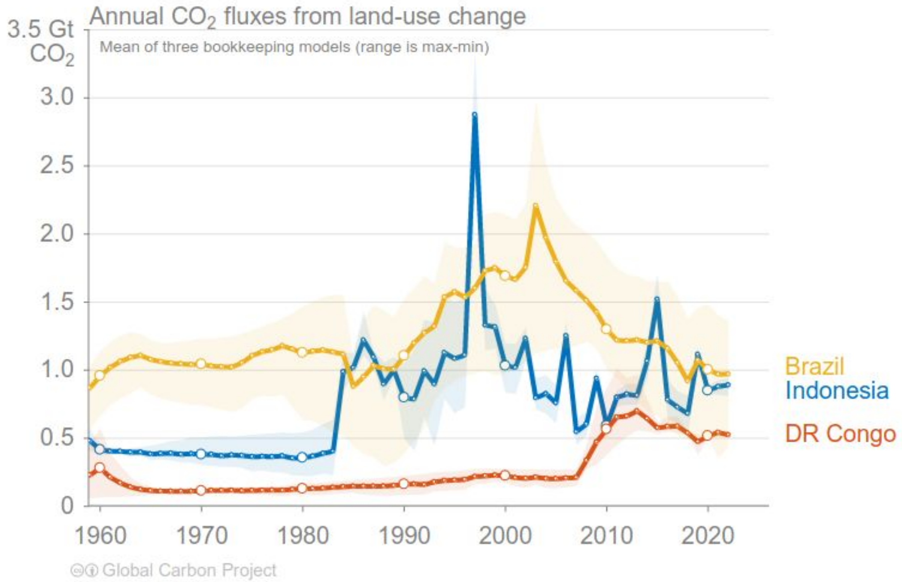
http://shrinkthatfootprint.com/carbon-emissions-and-sinks

Regional patterns of land-use change emissions

Land-use emissions are high in the tropics, driven largely by deforestation. Net sinks occur in regions of re/afforestation such as parts of Europe and China.

The top three emitters over 2013–2022 – Brazil, Indonesia, and the Democratic Republic of the Congo – contribute 55% of the global net land-use emissions.





The peak in Indonesia in 1997 was the Indonesian peat fires.

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L’Italia e la deforestazione in Amazzonia

Italia primo importatore in Europa di carne brasiliana: dove finisce e perché non viene dichiarato. L’anticipazione di PresaDiretta

Su Rai3 alle 21,20 andranno in onda due inchieste strettamente legate fra loro "Guerra all'Amazzonia" e "Troppa carne a buon mercato". Dove finisce la tonnellata di bovini brasiliani che importiamo? Non solo preparati, ma anche bresaola e molto altro. E c'è un problema: l'etichettatura

di F. Q. | 8 FEBBRAIO 2021

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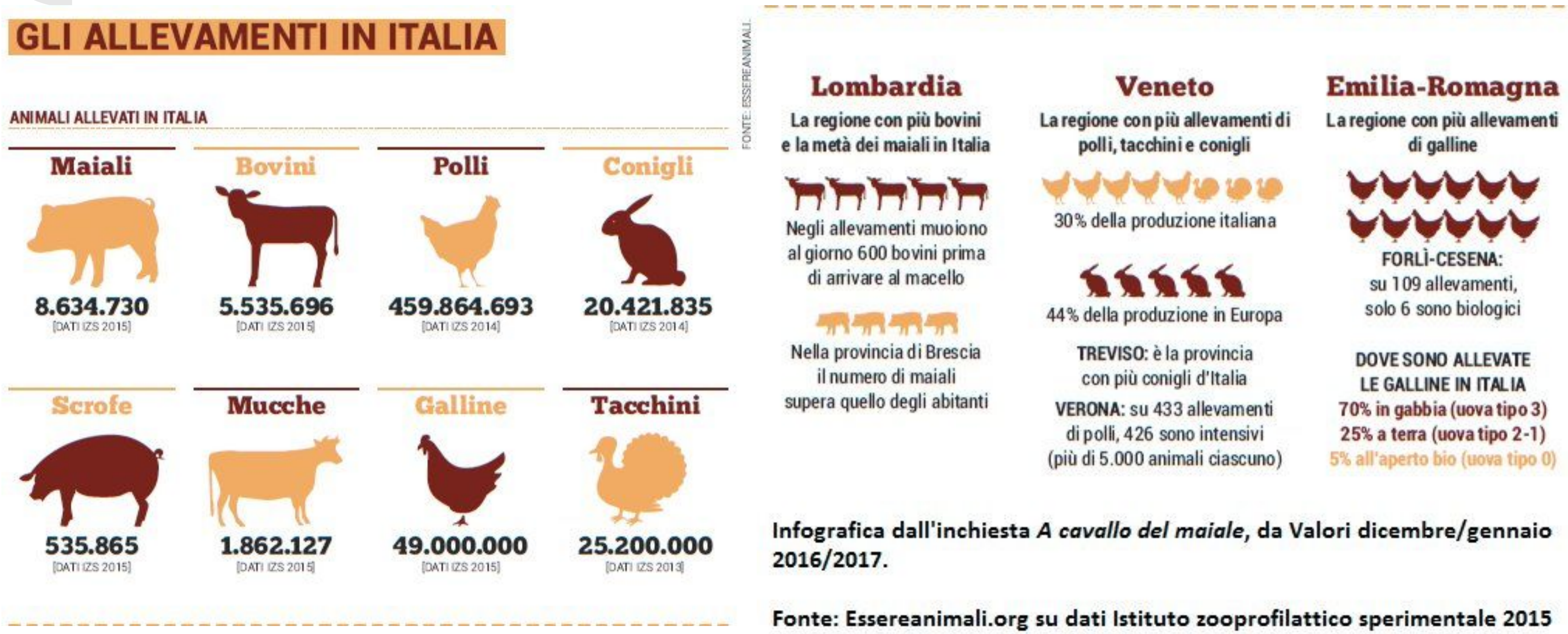
L’industria zootecnica in Italia



Infografica dall'inchiesta *A cavallo del maiale*, da Valori dicembre/gennaio 2016/2017.

Fonte: Essereanimali.org su dati Istituto zooprofilattico sperimentale 2015

https://valori.it/infografica-litalia-nella-stalla-lallevamento-e-intensivo/

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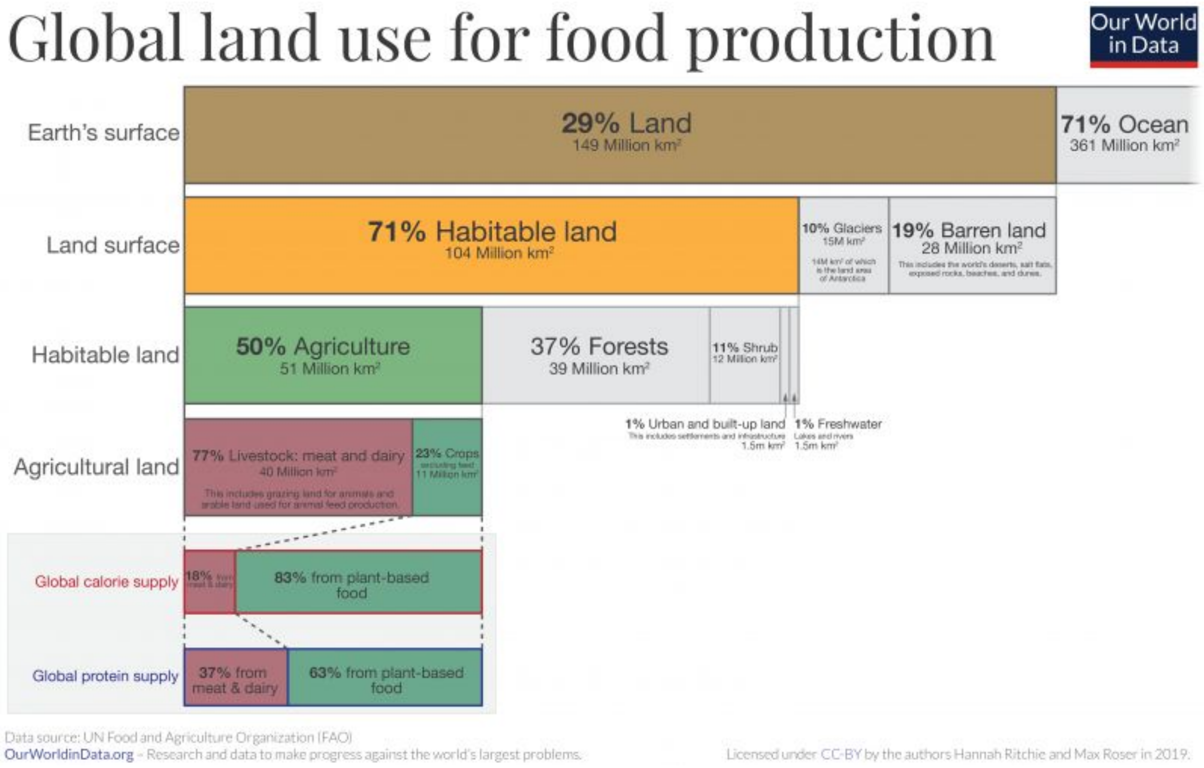

https://ourworldindata.org/global-land-for-agriculture

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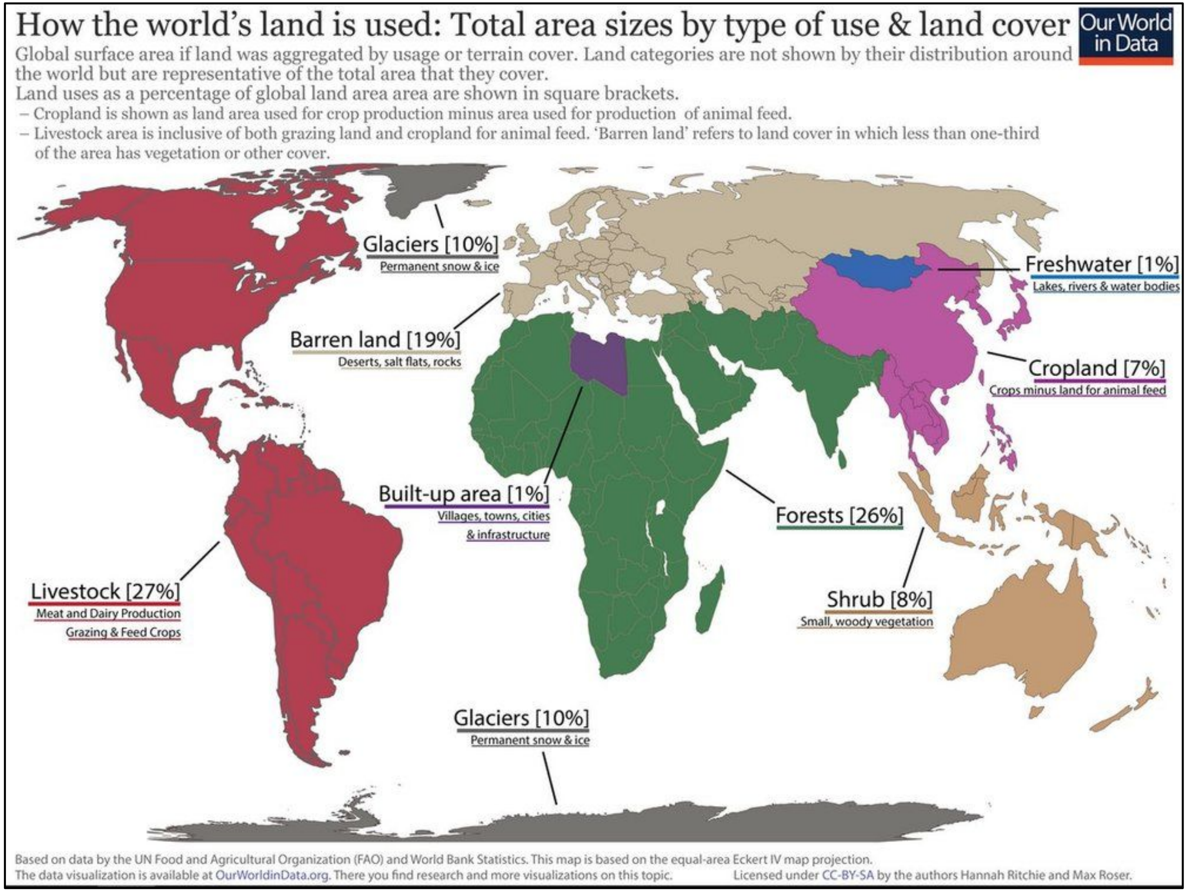

https://ourworldindata.org/uploads/2013/10/World-Map-by-Land-Use-01.png

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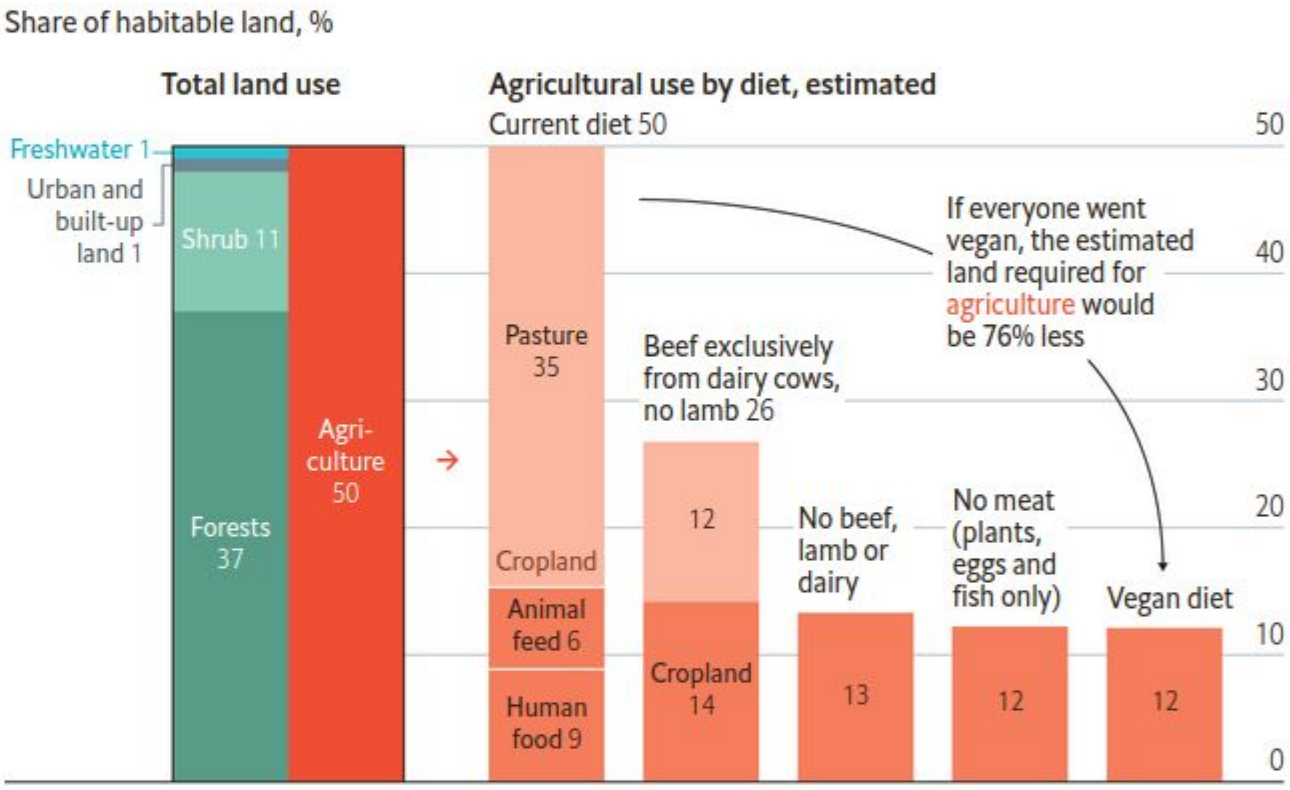

Sources: "Reducing food's environmental impact through producers and consumers", by Joseph Poore and Thomas Nemecek (2018); UN Food and Agriculture Organisation; Our World in Data

https://www.economist.com/graphic-detail/2022/01/28/if-everyone-were-vegan-only-a-quarter-of-current-farmland-would-be-needed

Poore & Nemecek 2018

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A word about fishing

nature

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nature › articles › article

Article | Published: 17 March 2021

Protecting the global ocean for biodiversity, food and climate

Enric Sala, Juan Mayorga, [...]Jane Lubchenco

Nature **592**, 397–402 (2021) | Cite this article

22k Accesses | **6** Citations | **1783** Altmetric | Metrics

An Author Correction to this article was published on 08 April 2021

Bottom trawling releases as much carbon as air travel, landmark study finds

Dragging heavy nets across seabed disturbs marine sediments, world's largest carbon sink, scientists report

▲ An area of seabed damaged by trawling. Bottom trawling by fishing boats pumps out 1 gigaton of carbon every year. Photograph: Howard Wood/COAST

Fishing boats that trawl the ocean floor release as much carbon dioxide as the entire aviation industry, according to a groundbreaking study.

Bottom trawling, a widespread practice in which heavy nets are dragged along the seabed, pumps out 1 gigaton of carbon every year, says the study written by 26 marine biologists, climate experts and economists and published in Nature on Wednesday.

The carbon is released from the seabed sediment into the water, and can increase ocean acidification, as well as adversely affecting productivity and biodiversity, the study said. Marine sediments are the largest pool of carbon storage in the world.

https://www.nature.com/articles/s41586-021-03371-z

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nature sustainability

BRIEF COMMUNICATION

https://doi.org/10.1038/s41893-020-00603-4

Check for updates

The carbon opportunity cost of animal-sourced food production on land

Matthew N. Hayek[1], Helen Harwatt[2], William J. Ripple[3] and Nathaniel D. Mueller[4,5]

Extensive land uses to meet dietary preferences incur a 'carbon opportunity cost' given the potential for carbon sequestration through ecosystem restoration. Here we map the magnitude of this opportunity, finding that shifts in global food production to plant-based diets by 2050 could lead to sequestration of 332–547 $GtCO_2$, equivalent to 99–163% of the CO_2 emissions budget consistent with a 66% chance of limiting warming to 1.5 °C.

Restoration of native ecosystems, including forests, is a land-based

to the past decade of global fossil fuel emissions. The largest potential for negative emissions—74 GtC or 48% of the global total—lies in upper-middle-income countries (Fig. 2), which will further increase as meat and dairy production expand. This is approximately equal to the past 19 years of fossil fuel emissions in these countries. In high-income countries, in which animal-sourced food demand is high but plateauing[8], the total carbon opportunity cost of animal-sourced food production is 32 GtC, approximately equal to the past 9 years of their domestic fossil fuel emissions.

Vegan diet:
547 GtCO2 / 30yr = 18.23 GtCO2/yr

To understand the potential future consequences of animal-sourced food consumption on global CO_2 budgets, we modelled land use of three global dietary scenarios to the year 2050 relative to the present day (base year 2015). The net CO_2 balance was calculated for a business-as-usual (BAU) diet following economic trends[12], a healthier diet with approximately 70% meat reduction globally relative to BAU[13] (the EAT-*Lancet* Commission or ELC diet) and a vegan (VGN) diet with no animal-sourced foods[8].

NATURE SUSTAINABILITY

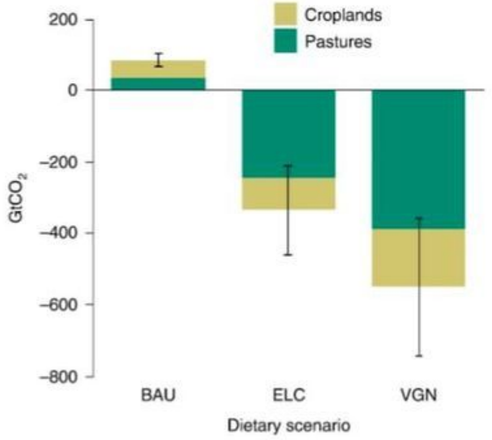

Fig. 3 | Cumulative changes in terrestrial carbon from three dietary scenarios in 2050: BAU, ELC and VGN. Scenarios do not include abated emissions associated with agricultural production (for example, ref. [7]). Positive CO_2 indicates a loss of ecosystem vegetation carbon and emissions to the atmosphere; negative indicates CO_2 removal via vegetation growth. Error bars are 95% confidence intervals, reflecting various estimates of potential vegetation and distributions of cropland removal from low- and high-carbon biomes.

https://www.nature.com/articles/s41893-020-00603-4.epdf (2020); https://scientistswarning.forestry.oregonstate.edu/sites/default/files/Hayek2020.pdf

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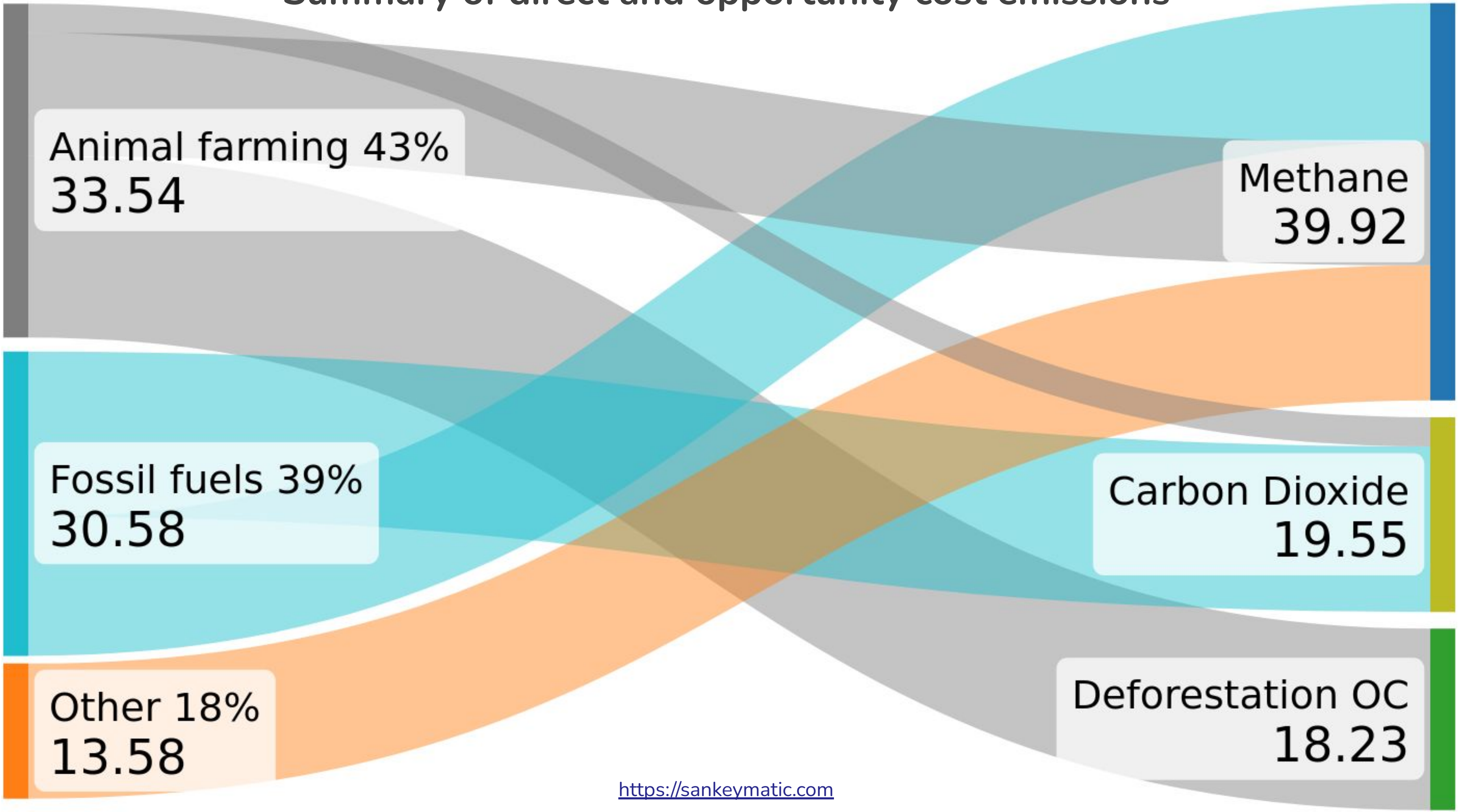
Including direct and indirect sources:

CO_2 fossil fuels → 0.85 x 0.5 x 39.1 = 16.62 Gt/yr
CO_2 animal farming → 0.15 x 0.5 x 39.1 = 2.93 Gt/yr
CO_2 opportunity cost animal farming → 18.23 Gt/yr
CH_4 fossil fuels → 0.35 x 39.93 = 13.96 $GtCO_2eq$/yr
CH_4 animal farming → 0.31 x 39.93 = 12.38 $GtCO_2eq$/yr
CH_4 other sources → 0.34 x 39.93 = 13.58 $GtCO_2eq$/yr

Fossil fuels: 39% | Animal farming: 43% | Other: 18%

Summary of direct and opportunity cost emissions



https://sankeymatic.com

1. Is climate changing? Is it caused by human activities? Is this debated by experts?
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5. What can/should we do?

Considering the effects of emissions *and* the opportunity cost, it is caused by fossil fuels *and* by animal agriculture, in comparable amounts

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REDUCE emissions urgently, deeply and rapidly, while ensuring an orderly, just transition;

Individually / Systematically

REMOVE CO_2 from the atmosphere in vast quantities;

- Technology (?)
- Reforestation

REPAIR broken parts of the climate system, starting with the Arctic, to try and reverse local changes and stop the cascade effects of those changes through global climate systems.

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2. Can we foresee the consequences of climate change?
3. Which are its physical causes?
4. Which human activities are more impactful?
5. What can/should we do?

- Support/become activists
- Talk, spread information
- Change individual habits

PROJECT DRAWDOWN

https://drawdown.org/solutions/table-of-solutions

* *Gigatons CO2 Equivalent Reduced / Sequestered (2020–2050)*

SOLUTION	SECTOR(S)	SCENARIO 1 *	SCENARIO 2 *
Reduced Food Waste	Food, Agriculture, and Land Use / Land Sinks	88.50	102.20
Plant-Rich Diets	Food, Agriculture, and Land Use / Land Sinks	78.33	103.11
Family Planning and Education	Health and Education	68.90	68.90
Refrigerant Management	Industry / Buildings	57.15	57.15
Tropical Forest Restoration	Land Sinks	54.45	85.14
Onshore Wind Turbines	Electricity	46.95	143.56
Alternative Refrigerants	Industry / Buildings	42.73	48.75
Utility-Scale Solar Photovoltaics	Electricity	40.83	111.59
Clean Cooking	Buildings	31.38	76.34
Distributed Solar Photovoltaics	Electricity	26.65	64.86
Electric Cars	Transportation	7.66	9.76
Smart Thermostats	Electricity / Buildings	6.91	7.25

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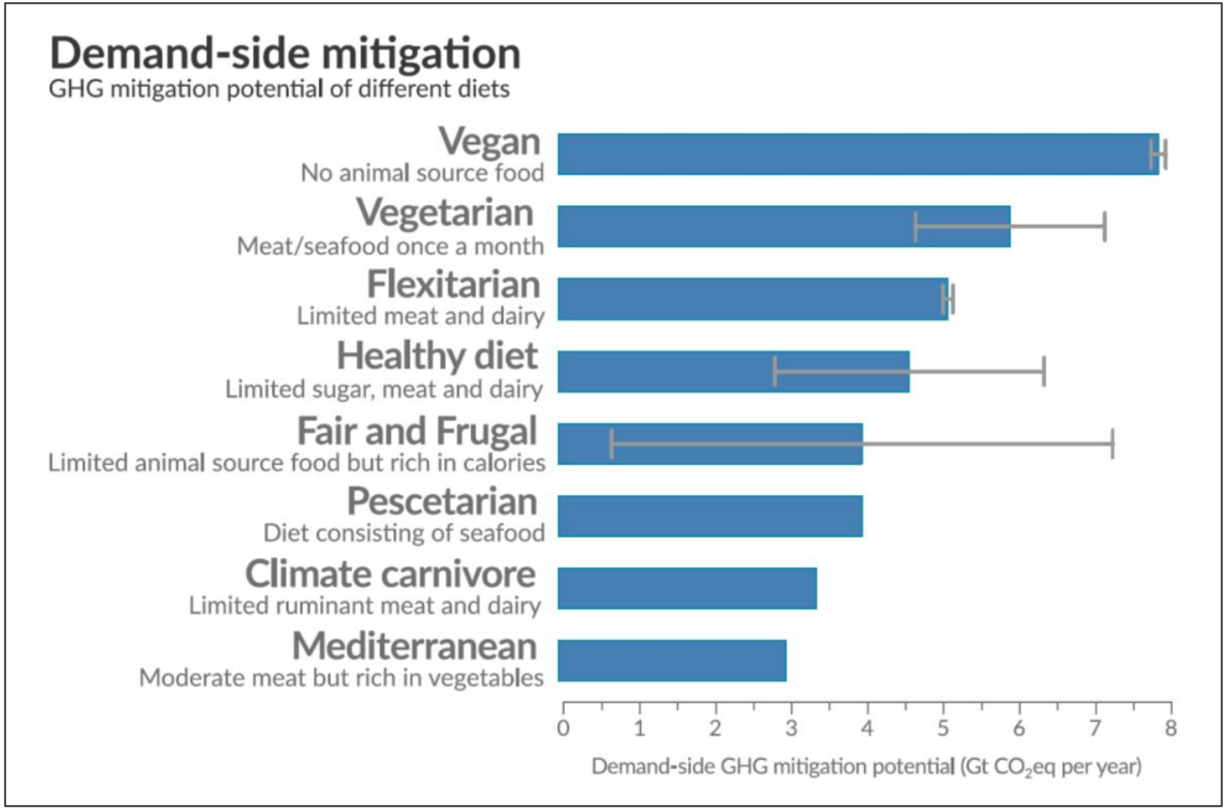
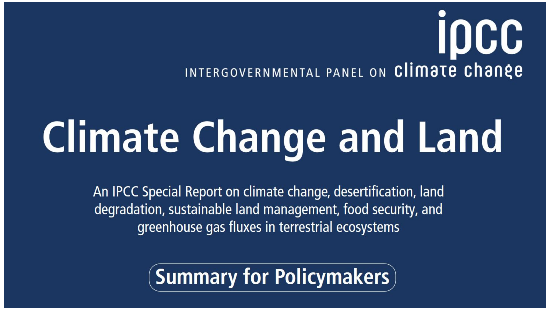
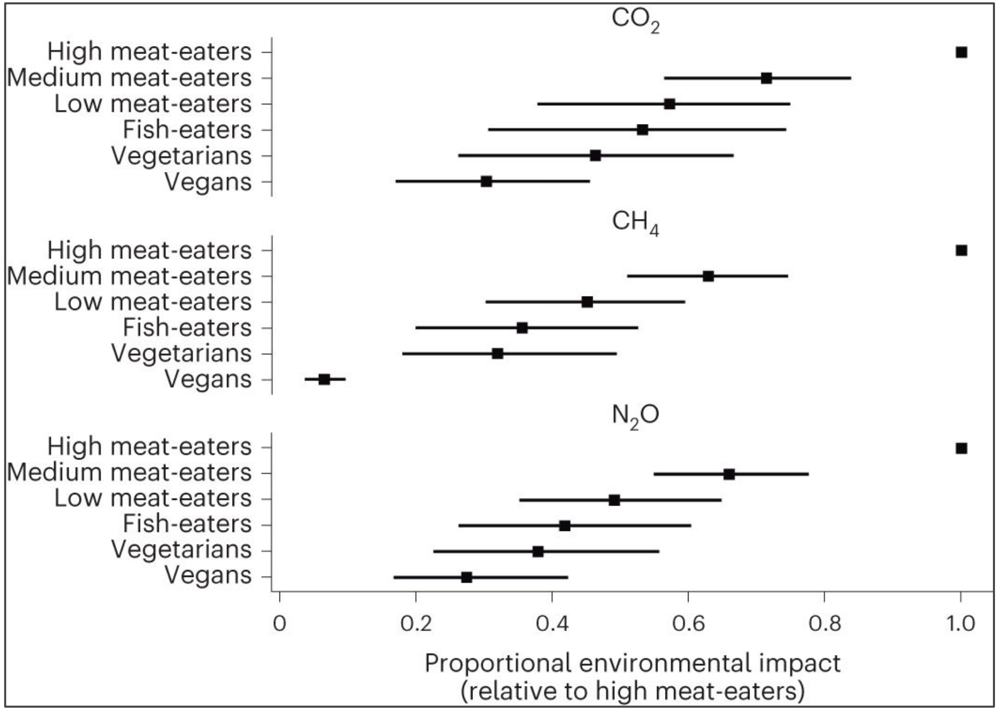


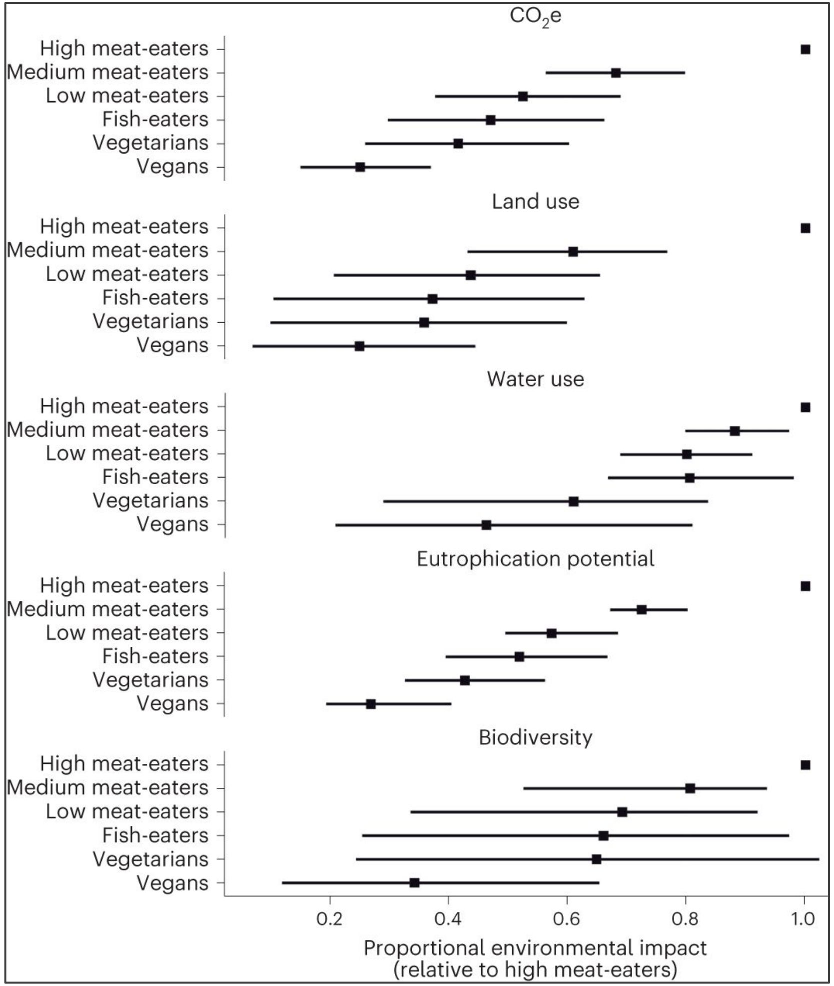


https://www.ipcc.ch/site/assets/uploads/2019/08/Fullreport-1.pdf

Vegan diet massively cuts environmental damage, study shows

Detailed analysis finds plant diets lead to 75% less climate-heating emissions, water pollution and land use than meat-rich ones





https://www.nature.com/articles/s43016-023-00795-w

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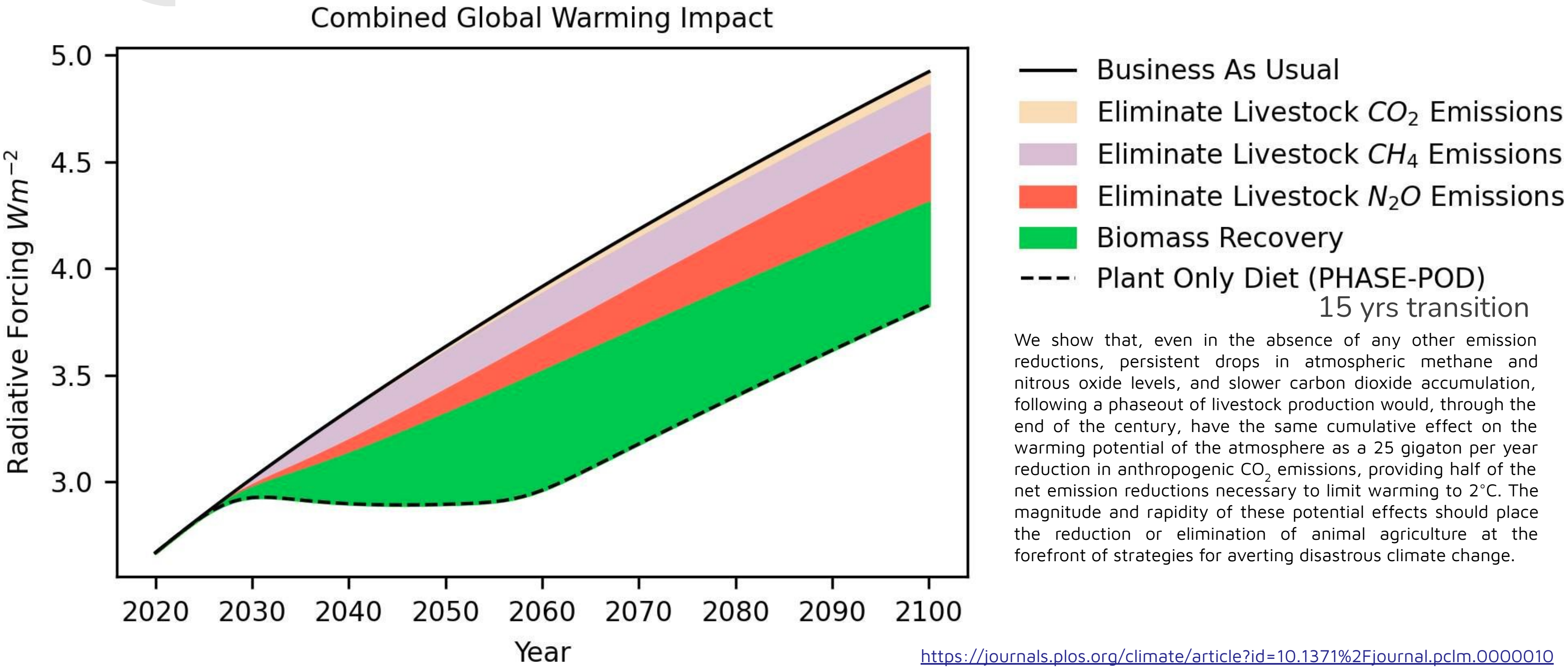
PLOS CLIMATE

OPEN ACCESS PEER-REVIEWED

Eisen & Brown 2022



15 yrs transition

We show that, even in the absence of any other emission reductions, persistent drops in atmospheric methane and nitrous oxide levels, and slower carbon dioxide accumulation, following a phaseout of livestock production would, through the end of the century, have the same cumulative effect on the warming potential of the atmosphere as a 25 gigaton per year reduction in anthropogenic CO_2 emissions, providing half of the net emission reductions necessary to limit warming to 2°C. The magnitude and rapidity of these potential effects should place the reduction or elimination of animal agriculture at the forefront of strategies for averting disastrous climate change.

https://journals.plos.org/climate/article?id=10.1371%2Fjournal.pclm.0000010

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How about free-range farming?
It's NOT the solution

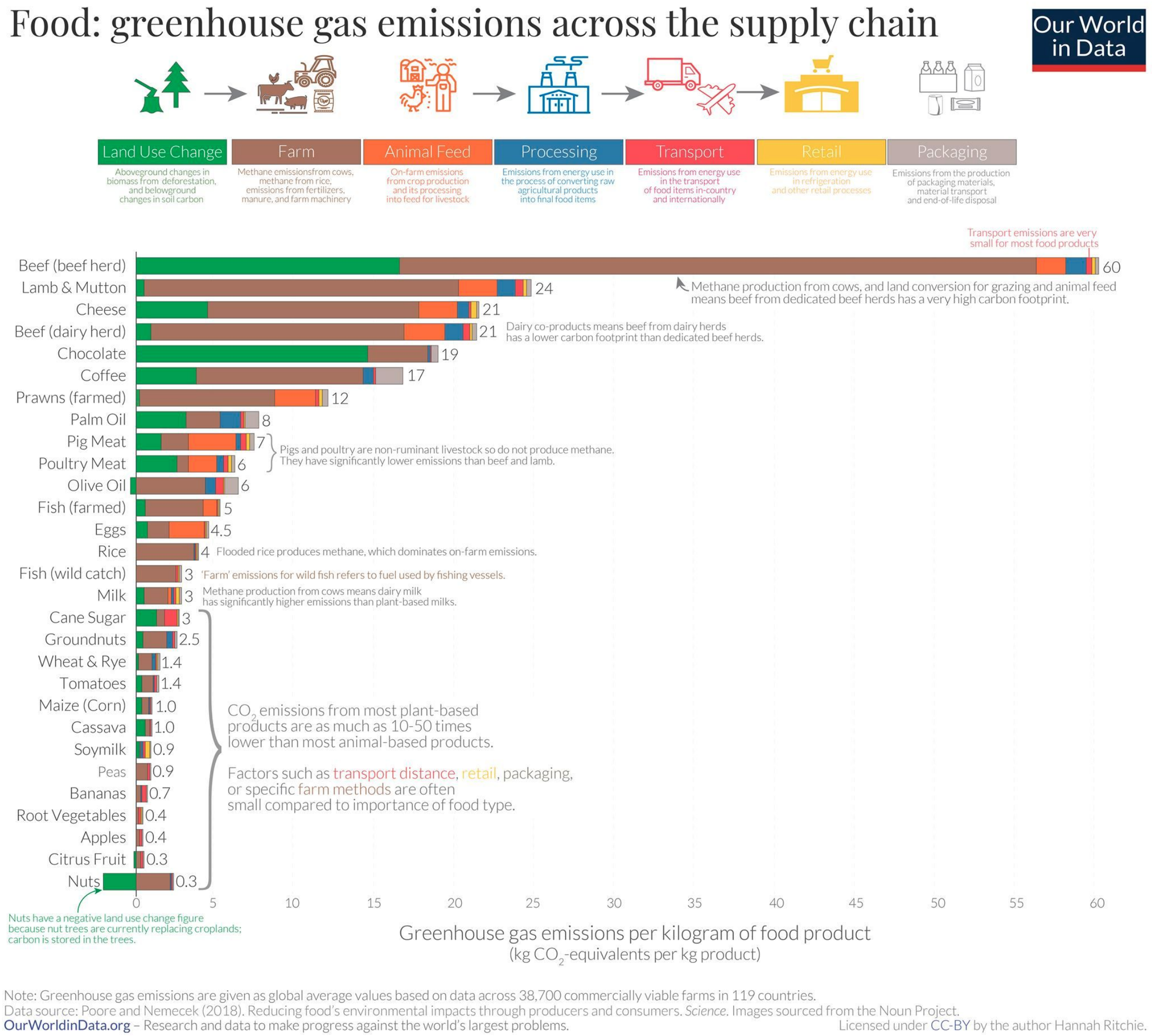
Reducing food's environmental impacts through producers and consumers

J. Poore[1,2]* and T. Nemecek[3]

Food's environmental impacts are created by millions of diverse producers. To identify solutions that are effective under this heterogeneity, we consolidated data covering five environmental indicators; 38,700 farms; and 1600 processors, packaging types, and retailers. Impact can vary 50-fold among producers of the same product, creating substantial mitigation opportunities. However, mitigation is complicated by trade-offs, multiple ways for producers to achieve low impacts, and interactions throughout the supply chain. Producers have limits on how far they can reduce impacts. Most strikingly, impacts of the lowest-impact animal products typically exceed those of vegetable substitutes, providing new evidence for the importance of dietary change. Cumulatively, our findings support an approach where producers monitor their own impacts, flexibly meet environmental targets by choosing from multiple practices, and communicate their impacts to consumers.

AAAS
Science

https://science.sciencemag.org/content/sci/360/6392/987.full.pdf



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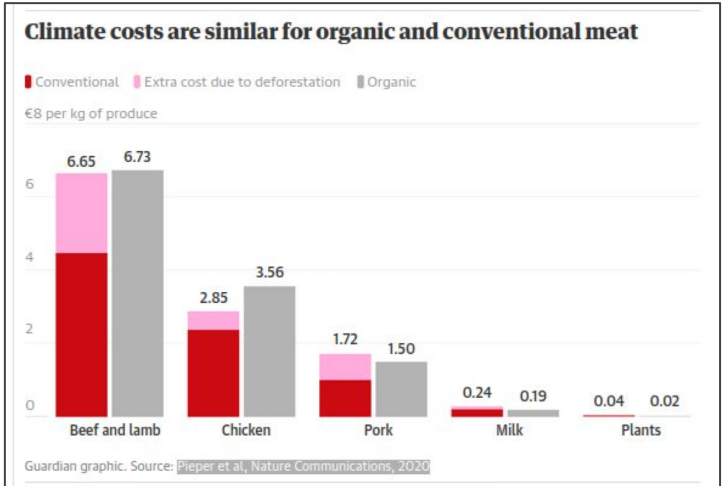


The study, published in the journal Nature Communications, used the German government's estimate of climate damage costs - €180 per tonne of CO2 - which is based on work by the Intergovernmental Panel on Climate Change. It found the farmgate price of beef would have to be more than €6/kg higher to cover climate costs and about €3/kg more for chicken.

The quantification includes the determination of food-specific GHG emissions —also known as carbon footprints[39]—occurring from cradle to farmgate by the usage of a material-flow analysis tool. Carbon footprints are understood within this paper in line with Pandey et al.[71] where all climate-relevant gases, which (in addition to CO_2) include methane (CH_4) and nitrous oxide (N_2O), are considered. Their 100-year CO_2 equivalents conversion factors are henceforth defined as 28 and 265, respectively[72]. Here, the material-flow analysis tool GEMIS (Global Emission model for Integrated Systems)[44] is used, which offers data for a variety of conventionally farmed foodstuff. As GEMIS data focus on emissions from conventional agricultural systems, we carried out the distinction to organic systems ourselves. We determined the difference in GHG emissions between the systems by applying meta-analytical methods to studies comparing the systems' GHG emissions directly to one another. Meta-analysis is commonly used in the agricultural context, for example, when comparing the productivity of both systems[57–59] or their performance[1].

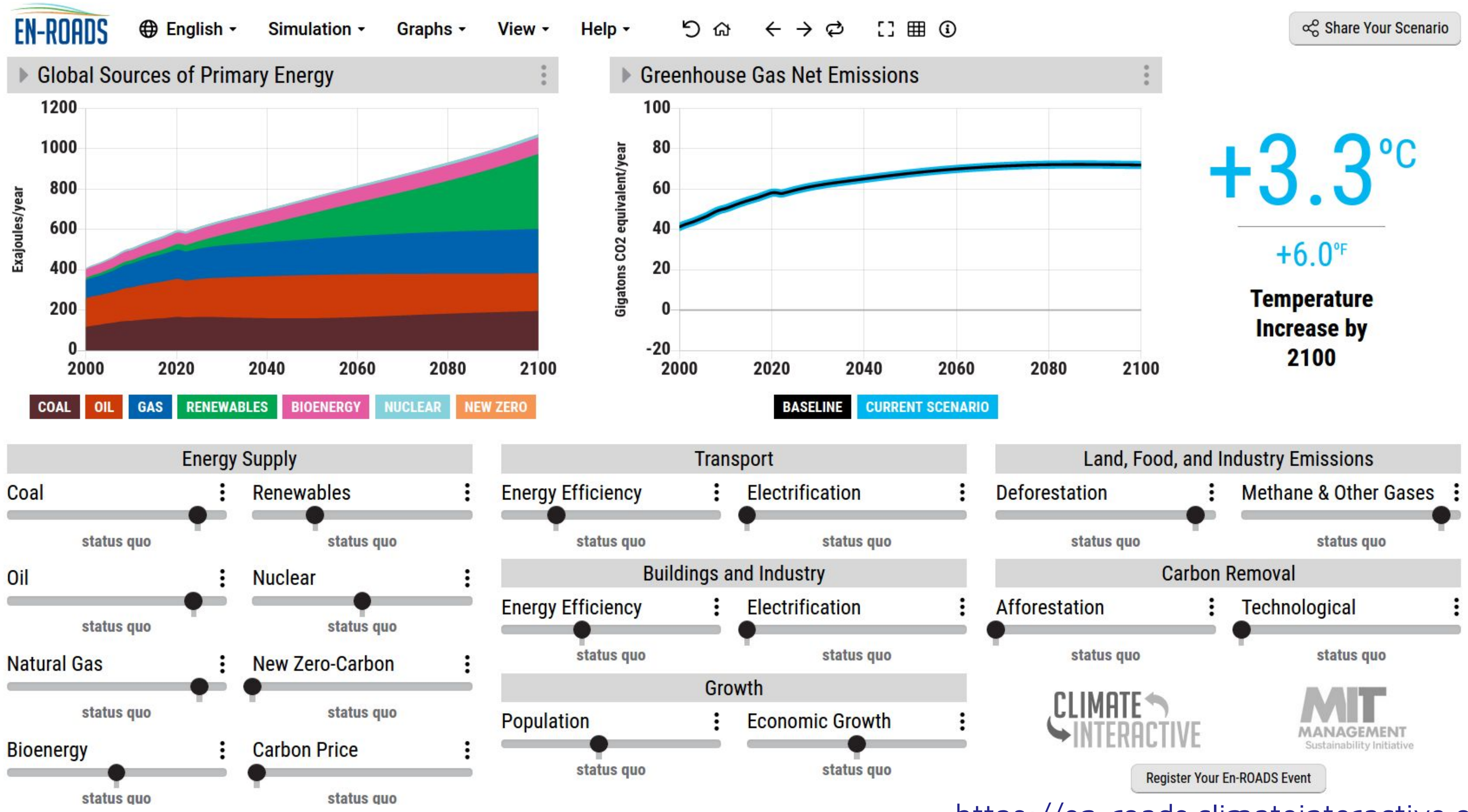
Table 1 Emission data for food-specific, narrow and broad categories (following the classification from the German Federal Office of statistics[88]).

Emission data (in kg CO_2eq/kg product)											
Broad categories [b]	Prod. method			Narrow categories [n]	Prod. method			Food-specific [i]	Prod. method		
	Conv. [$E_{b,conv}$]	With LUC	Org. [$E_{b,org}$]		Conv. [$e_{b,n,conv}$]	With LUC	Org. [$e_{b,n,conv}$]		Conv. [$g_{b,n,i,conv}$]	With LUC	Org. [$g_{b,n,i,org}$]
Plant-based	0.20	/	0.11	Vegetables	0.04	/	0.02	Field Vegetables	0.03	/	0.02
								Tomatoes	0.39	/	0.22
				Fruit	0.25	/	0.14	Fruit	0.25	/	0.14
				Cereal	0.36	/	0.21	Rye	0.22	/	0.13
								Wheat	0.38	/	0.21
								Oat	0.36	/	0.21
								Barley	0.33	/	0.19
				Root Crops	0.06	/	0.04	Potatoes	0.06	/	0.04
				Legumes	0.03	/	0.02	Beans	0.03	/	0.02
				Oilseed	1.02	/	0.58	Rapeseed	1.02	/	0.58
Animal-based	8.90	(13.38)	13.39	Eggs	1.17	(1.18)	1.76	Eggs	1.17	(1.18)	1.76
				Poultry	13.16	(15.81)	19.80	Broilers	13.16	(15.81)	19.80
				Ruminants	24.84	(36.95)	37.37	Beef	24.84	(36.95)	37.37
				Pork	5.54	(9.56)	8.34	Pork	5.54	(9.56)	8.34
Dairy	1.09	(1.33)	1.05	Milk	1.09	(1.33)	1.05	Milk	1.09	(1.33)	1.05

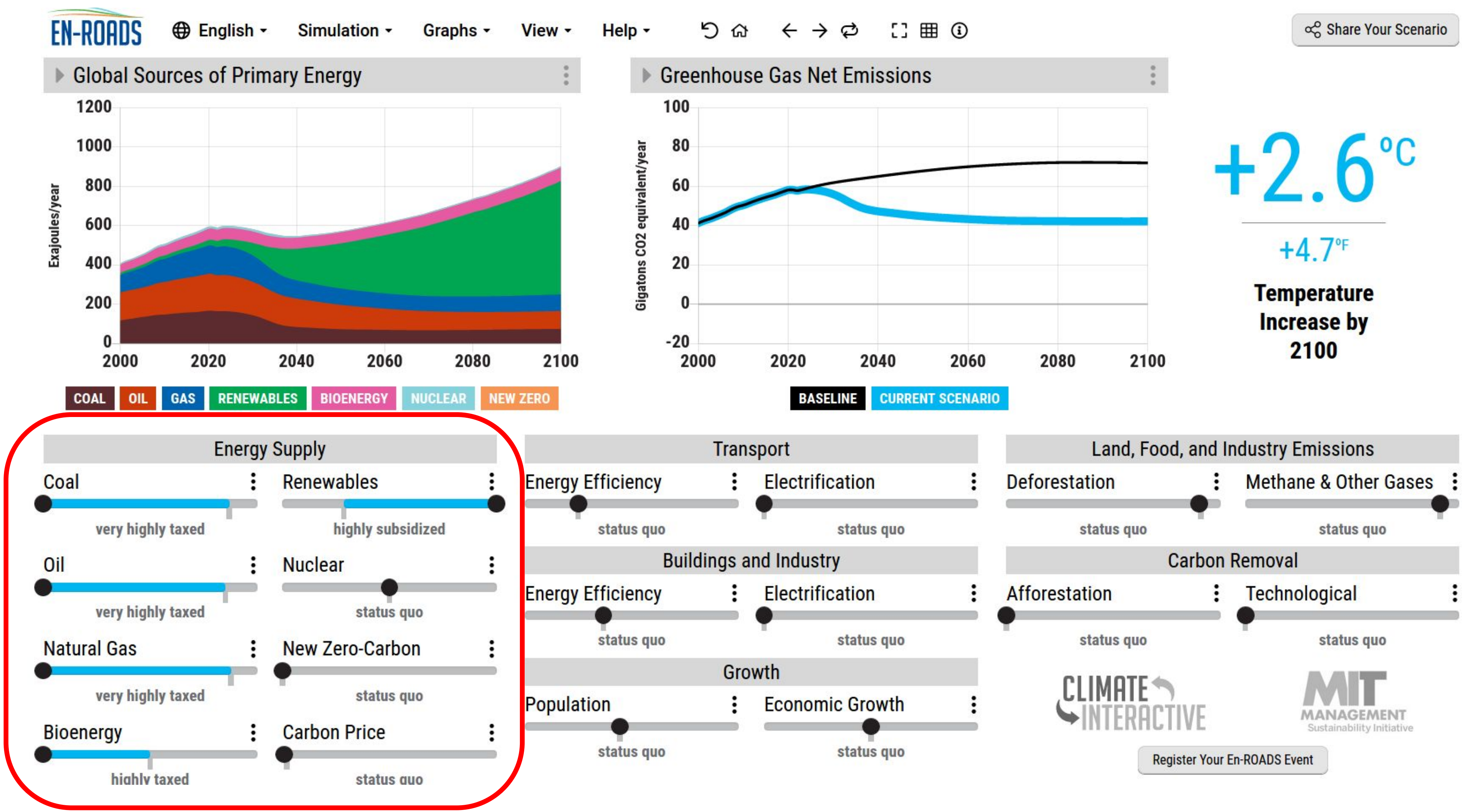
Food-specific emission data for conventional production was derived from Global Emissions Model for Integrated Systems (GEMIS)[44] and aggregated to narrow and broad categories with German production data[88]; differentiation between conventional and organic production was derived with a meta-analytical approach (for details refer to the "Method and data" section and Supplementary Note 1 and Table 1); land-use change (LUC) data are approximated to be the LUC emissions of soymeal fodder, emissions of it are calculated with the method of Ponsioen and Blonk[45]. Emission data including LUC emissions are shown in brackets. Source data are provided as a source data file.

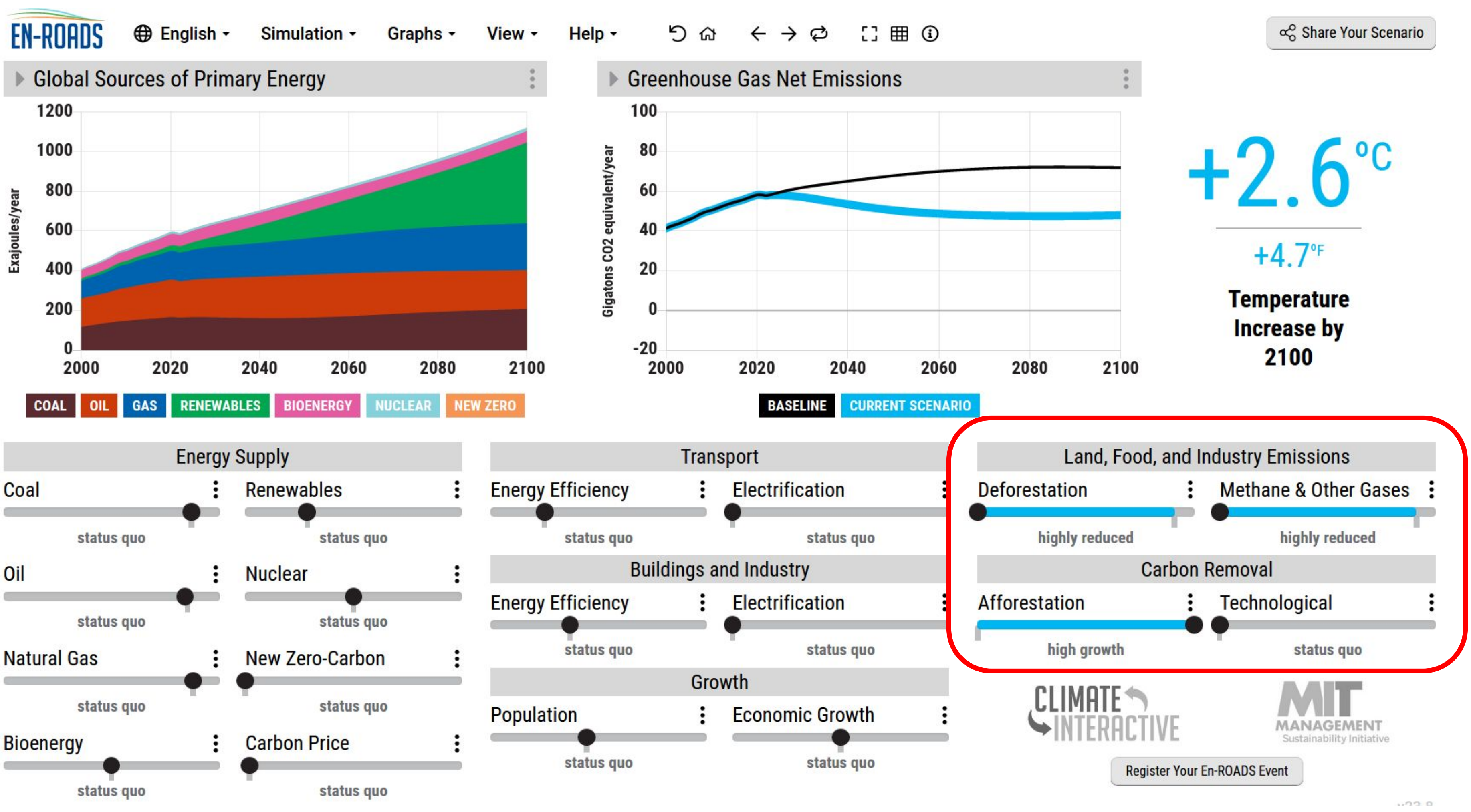
https://www.nature.com/articles/s41467-020-19474-6.pdf

https://www.theguardian.com/environment/2020/dec/23/organic-meat-production-just-as-bad-for-climate-study-finds



https://en-roads.climateinteractive.org/


EN-ROADS
English
Simulation
Graphs
View
Help
Share Your Scenario
Global Sources of Primary Energy
Exajoules/year
1200
1000
800
600
400
200
0
2000
2020
2040
2060
2080
2100
COAL
OIL
GAS
RENEWABLES
BIOENERGY
NUCLEAR
NEW ZERO
Greenhouse Gas Net Emissions
Gigatons CO2 equivalent/year
100
80
60
40
20
0
-20
2000
2020
2040
2060
2080
2100
BASELINE
CURRENT SCENARIO
+2.6°C
+4.7°F
Temperature Increase by 2100
Energy Supply
Coal
very highly taxed
Renewables
highly subsidized
Oil
very highly taxed
Nuclear
status quo
Natural Gas
very highly taxed
New Zero-Carbon
status quo
Bioenergy
highly taxed
Carbon Price
status quo
Transport
Energy Efficiency
status quo
Electrification
status quo
Buildings and Industry
Energy Efficiency
status quo
Electrification
status quo
Growth
Population
status quo
Economic Growth
status quo
Land, Food, and Industry Emissions
Deforestation
status quo
Methane & Other Gases
status quo
Carbon Removal
Afforestation
status quo
Technological
status quo
CLIMATE INTERACTIVE
MIT MANAGEMENT Sustainability Initiative
Register Your En-ROADS Event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Natural Gas
status quo
New Zero-Carbon
status quo
Bioenergy
status quo
Carbon Price
status quo
Transport
Energy Efficiency
status quo
Electrification
status quo
Buildings and Industry
Energy Efficiency
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Electrification
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Growth
Population
status quo
Economic Growth
status quo
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highly reduced
Carbon Removal
Afforestation
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1. Is climate changing? Is it caused by human activities? Is this debated by experts?
2. Can we foresee the consequences of climate change?
3. Which are its physical causes?
4. Which human activities are more impactful?
5. What can/should we do?

- Support/become activists
- Talk, spread information
- Change own habits, starting from **food**

Science
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HOME > SCIENCE > VOL. 360, NO. 6392 > REDUCING FOOD'S ENVIRONMENTAL IMPACTS THROUGH PRODUCERS AND CONSUMERS
RESEARCH ARTICLE

Reducing food's environmental impacts through producers and consumers

J. POORE AND T. NEMECEK Authors Info & Affiliations

SCIENCE • 1 Jun 2018 • Vol 360, Issue 6392 • pp. 987-992 • DOI: 10.1126/science.aaq0216

"A vegan diet is probably the single biggest way to reduce your impact on planet Earth, not just greenhouse gases, but global acidification, eutrophication, land use and water use," said Joseph Poore, at the University of Oxford, UK, who led the research. "It is far bigger than cutting down on your flights or buying an electric car," he said, as these only cut greenhouse gas emissions.


IL CASHEWFICIO


BEYOND MEAT
BEYOND BEEF
PLANT-BASED
20G OF PLANT PROTEIN PER SERVING
NO SOY NO GLUTEN NO GMOS
25% LESS SAT. FAT


NEXT LEVEL BURGER
VEGANE BURGER PATTIES
20g
227g


10
GOLOSISSIMI
DOLCI
VEGANI


isola Bio
ALMOND
RISO CHOQUINOA
RISO MANDORLA
KAMUT
RICE

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ANIMALS SLAUGHTERED FOR FOOD EVERY SECOND

THESE ARE THE NUMBERS OF ANIMALS SLAUGHTERED WORLDWIDE BY THE MEAT, EGG, AND DAIRY INDUSTRIES SINCE YOU OPENED THIS WEBPAGE.

IT HAS BEEN 10 SECONDS

318,350 WILD CAUGHT FISH

20,076 CHICKENS

12,471 FARMED FISH

948 DUCKS

476 PIGS

385 RABBITS

226 GEESE

203 TURKEYS

176 SHEEP

144 GOATS

98 CATTLE

23 RODENTS

20 PIGEONS & BIRDS

8 BUFFALOES

2 HORSES

1 DONKEYS

1 CAMELIDS

Thanks to Consider Veganism for counter statistics

https://theveganecalculator.com/animal-slaughter/

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ANIMALS SLAUGHTERED FOR FOOD EVERY SECOND

THESE ARE THE NUMBERS OF ANIMALS SLAUGHTERED WORLDWIDE BY THE MEAT, EGG, AND DAIRY INDUSTRIES SINCE YOU OPENED THIS WEBPAGE.

IT HAS BEEN 5 HOURS AND 3 SECONDS

103,909,897 WILD CAUGHT FISH	6,552,962 CHICKENS	4,070,697 FARMED FISH	309,330 DUCKS
155,528 PIGS	125,504 RABBITS	73,610 GEESE	66,212 TURKEYS
57,498 SHEEP	46,954 GOATS	32,008 CATTLE	7,538 RODENTS
6,391 PIGEONS & BIRDS	2,764 BUFFALOES	521 HORSES	344 DONKEYS
	347 CAMELIDS		

Thanks to Consider Veganism for counter statistics

https://theveganCalculator.com/animal-slaughter/

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INAF and research institutes should **spread awareness** and **behave virtuously:** *towards zero food waste at meetings, increase plant-based option and minimize/eliminate meat, dairy and fish, improve energy efficiency, reduce/cut flights*

https://green.inaf.it/2023/08/08/impatto-delle-scelte-alimentari-sulle-emissioni-e-i-cambiamenti-climatici/
https://orsomerlin.wordpress.com/2020/04/06/perche-gli-allevamenti-sono-molto-piu-dannosi-per-il-clima-di-quanto-si-creda/

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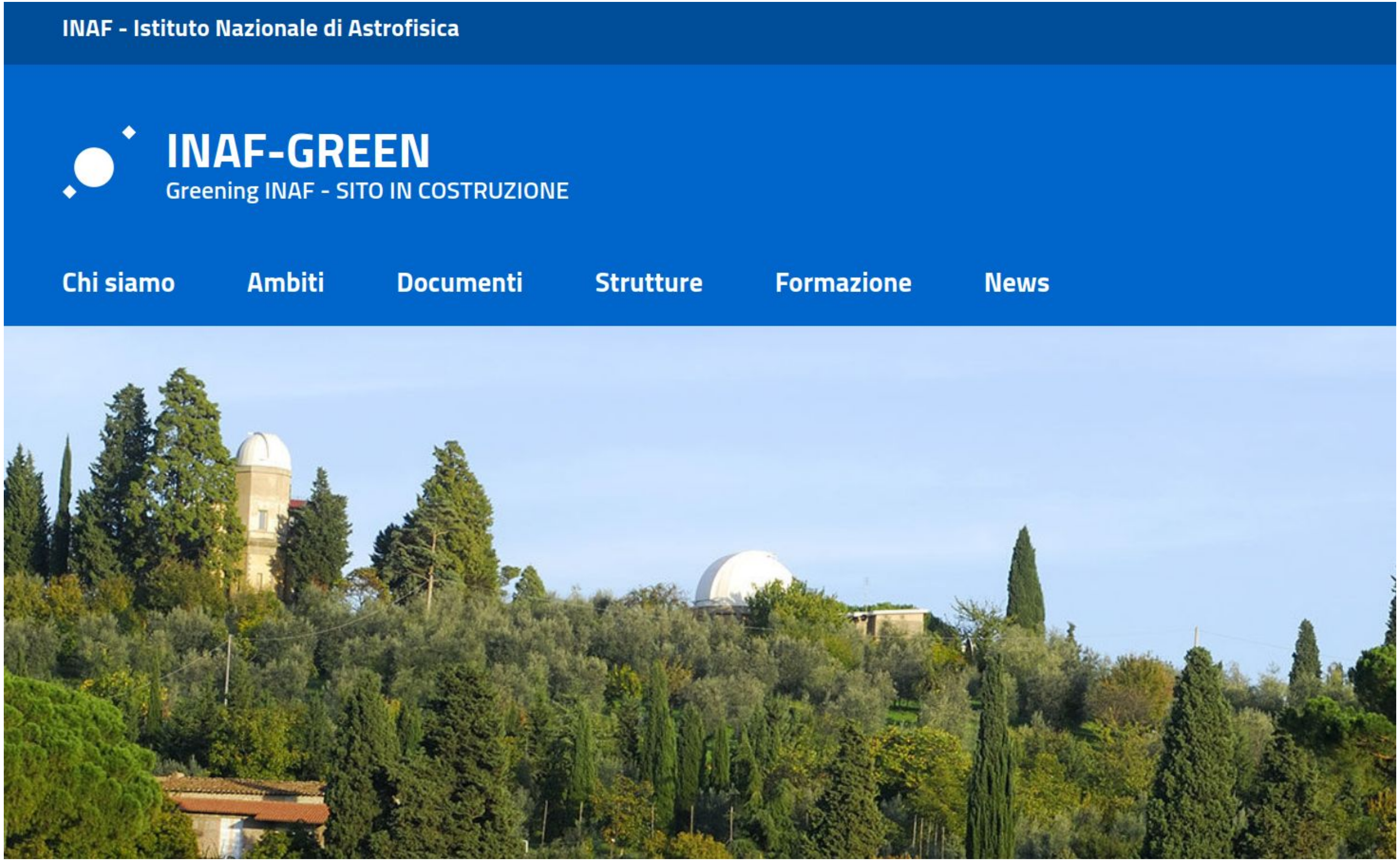

Recommendations for green practices at INAF sponsored conferences

Research institutions must spread knowledge and be at the forefront of the path towards social awareness of environmental issues, climate change, and their mitigation. Meetings, conferences and any social event should promote environmentally friendly practices, giving virtuous examples.
We provide a short list of recommendations, hoping that INAF will receive and approve them for all future conferences; clearly, this would also have a positive impact on its public image.

Generally, the selection of the location, technical support, catering company, conference material providers and logistic support should follow green procurement procedures. All organizers, attendees, contractors and collaborators should be aware that the conference strives to be as environmentally friendly as possible.

Attendance
- All conferences should allow remote attendance with low cost and without penalty (e.g. no requirement for in person attendance to give talks).

- Attendants should be encouraged to travel by train and public transport whenever feasible.

- Locations for events should be accessible by local transport and have accommodation within walking distance.

Catering
- It is widely accepted that food from meat, fish and dairy products have a strong impact on the environment and on climate change in particular (see https://green.inaf.it/2023/08/08/impatto-delle-scelte-alimentari-sulle-emissioni-e-i-cambiamenti-climatici/). We strongly recommend that for coffee breaks, social dinners and any event involving food, the offer of meat, fish and dairy is strongly reduced if not completely eliminated, favoring plant-based options.

- In general, food waste should be limited to the very minimum. Non consumed food should be gathered and given to charity associations.

Supplies
- Conference publicity or information should be provided preferably in digital form or, if not possible, on sustainable materials

- Conference freebies, if absolutely necessary, should be as eco-friendly as possible and reusable or recyclable; we recommend items which encourage environmentally friendly practices such as cotton tote bags, aluminum water bottles or conserved local food items. It could also be positive if the attendee was allowed a choice of gadgets, some people will refuse all of them, and, if people do pick one there is a good chance they will use the item.

- There should be ample, well signposted, recycle bins for paper, plastic, glass and metals where appropriate.

- Whenever possible reusable supplies should be made available for other meetings.

A conference should evaluate the carbon impact of their event, inform the attendees of the results and consider funding carbon offsets to counter the impact.

Ideas for encouraging good practises.

- Organize local bike / e-bike exploration activities
- Highlight local sustainable restaurants and cafes, offering plant-based options
- Include sustainable sightseeing activities
- Plant a tree for each attendee (as a freebie??)
- Plan a discussion of the environmental impact of the research
- Let the local press know you have a sustainable conference

https://green.inaf.it/wp-content/uploads/2024/03/Recommendations-for-green-practices-at-INAF-sponsored-rence-UK.pdf

Conclusions

1. Climate is changing, because of human activities, and there is 100% consensus about this among experts
2. We can foresee the consequences of climate change within large uncertainties, but it’s probably going to be worse than expected for the ecosystem and the biosphere
3. Climate change is mostly caused by CO_2 (historically) and CH_4 (current rate of warming) emissions,
4. caused by fossil fuels production/consumption and animal farming, in comparable amounts if we include opportunity cost from deforestation
5. We (as scientists and human beings) should talk about this, spread awareness, and possibly change our habits

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Online resources

https://orsomerlin.wordpress.com/2020/04/06/perche-gli-allevamenti-sono-molto-piu-dannosi-per-il-clima-di-quanto-si-creda/

https://chpdb.it/_climate_dash/

https://www.ncdc.noaa.gov/sotc/global/

https://www.carbonbrief.org/mapped-how-every-part-of-the-world-has-warmed-and-could-continue-to-warm

https://www.carbonbrief.org/qa-how-do-climate-models-work

https://thevegancalculator.com/animal-slaughter/

https://www.carbonfootprint.com/calculator.aspx

https://en-roads.climateinteractive.org/scenario.html